AD-778 192

AN/TPQ-31 PERFORMANCE: DURING EVALUATION AS A HOSTILE WEAPON LOCATOR

Raytheon Company

Prepared for:

Marine Corps

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This report addresses the AN/TPQ-31 Counter Mortar Radar performance against various types of artillery weapons at Dahlgren, Virginia and Fort Sill, Oklahoma during the first week of December 1972 and from 23 January 1973 through 7 March 1973, respectively. An analysis of data recorded at the AN/TPQ-31 sites on 81 mm, 4.2 mm, 105 mm, 155 mm, 8" and 175 mm rounds is presented. Firing point miss distances of 108 meters on 81 mm rounds with 100% detection to 956 meters on 105 mm rounds with 67% detection are derived for the AN/TPQ-31.

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SUPPORT PROGRAM

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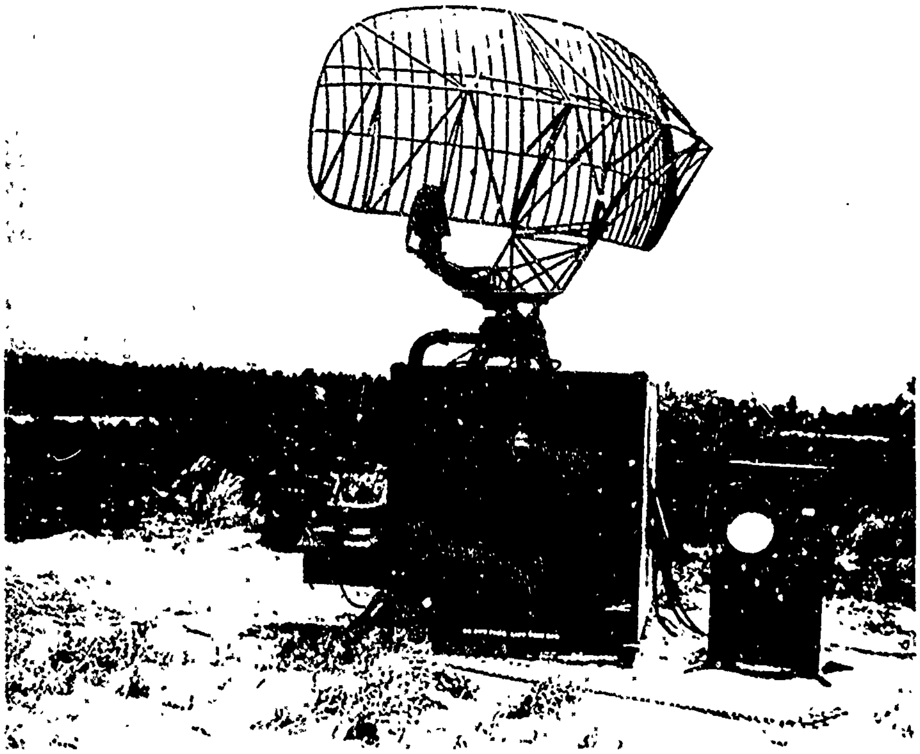

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ANNEXES: A - AN/TPQ-31 Radar Set Equipment Characteristics - Radar Performance Parameters

B - Background Information

C - AN/TPQ-31( ) Radar Set Equipment Performance Objectives

D - Wang Computer Program

E - Dahlgren Test Data Analysis

F - Fort Sill Test Data Analysis

1. INTRODUCTION

a. Purpose - The primary purpose of this report is to provide a record of the performance of the AN/TPQ-31 during test firings, provided for the field evaluation, of similar type equipment being used as a hostile weapon locator. In addition, the report will also provide data for future comparison with the performance of the AN/TPQ-31's currently being modified by Raytheon Company under Contract M00027-72-C-0098.

b. Description -

(1) The AN/TPQ-31 Radar Set was designed to provide for direct interpretation by operators from a first round track of blips painted on a PPI scope by incoming mortar projectiles the location of the hostile weapons firing the

incoming mortar rounds. The AN/TPQ-31 Radar Set utilizes a doppler processor which eliminates stationary targets, and has a continuous 360 degree azimuth coverage at a range of 1 to 24 kilometers on targets of 0.015 sq. meters or larger. Target range and azimuth data is displayed on a 16 inch azimuth range indicator (PPI) for the operators. This indicator can be operated up to 100 feet from the radar set equipment shelter. The AN/TPQ-31 utilized by the Marine Corps during these firings included the 1967 modifications plus changes to the receiver chain to improve rain clutter and to the antenna system to increase its rotation speed from 15 RPM to 30 RPM. Additional details are contained in Annex A to this report.

c. Background -

(1) In October 1967, the Raytheon Company received a quick reaction contract from the Marine Corps to provide a 360° counter mortar radar for use in Viet Nam. Ten AN/UPS-1 air search radars designed in the mid 1950's were provided t Raytheon by the Marine Corps for limited modifications that would permit th[illegible] [illegible]e in the counter mortar role. Various features which may have been incorporated in a complete "design-for-the purpose" were of necessity not pursued. In February 1969 deployment of active units was started in Viet Nam. Careful siting of the radar system and constant vigilance on the part of the radar operator were found to be essential to the effectiveness of the system. Additional background details are contained in Annex B to this report.

(2) Currently the Marine Corps has a limited modification program with Raytheon to update the 1967 version of the AN/TPQ-31 using modern technology in specific sections of the radar. The transmitter-receiver chain is being modernized and current solid state signal and target data processing techniques introduced. These modifications are expected to significantly improve target detection and processing with the provision of manual, semiautomatic and automatic hostile

weapon location readout. The data collected by this report will be used in the field tests of this improved AN/TPQ-31( ). Additional performance objectives are contained in Annex C to this report.

2. DISCUSSION

a. This report is limited to the performance of the AN/TPQ-31 during firing exercises at Dahlgren, Va. and Ft. Sill, Oklahoma.

b. The objective of these firings was to demonstrate the feasibility of using radars similar to the AN/TPQ-31 as hostile artillery locators and/or designators, and to gain experience in their use for these purposes, in order that recommendations could be made for improving such equipment and for improving weapon locating methods. The philosophy of the firing tests was to progress through a series of tests beginning with projectiles of opportunity and culminating in firings which simulate as closely as possible actual operating conditions.

c. The evaluation firings were divided into two phases; the first phase at Dahlgren, Virginia, and the second at Fort Sill, Oklahoma.

d. During the evaluation, the AN/TPQ-31 was operated entirely by Marines. The Marine operational personnel were used to run the equipment, collect data, keep logs, and analyze the data.

(1) For information purposes, the following is supplied on the eight Marine Personnel involved:

NUMBER	RATE	MOS	DUTIES
1	S Sgt	5934	MCDEC Project NCO
1	Gy Sgt	5934	Radar Technicians
2	L/Cpl	5934	Radar Technicians
4	Pvt	0842	Radar Operators

(2) The project NCO and the team chief had prior experience with the AN/TPQ-31. The operators had no previous experience with the equipment.

(3) Raytheon contractor personnel were available at the site for the purpose of assisting the Marine technician in repairs that might be beyond his experience.

e. The firing point predictions listed in the data of Annexes E&F (Dahlgren and Ft. Sill, respectively) were arrived at through a backtrack procedure utilizing two methods:

(1) The basic AN/TPQ-31 manual method involving map plotting. This procedure starts with plotting, in radar coordinates, the first and last position of the radar track on a map. The distance between the two points is measured and divided by 2(N-1) where N is the number of antenna scans over the time of flight. The result is then plotted backward along the line of flight established between the two previously plotted points and establishes the firing point. This point is then read out in map coordinates. The operator derived firing point locations in the accompanying data to this report were based on a 25,000 to 1 scale map with no mask angle correction being utilized.

A plotting pin approximately 1/30 inch diameter may lead to an error of approximately 50 meters. With five measurements or plots made as described above, an expected error would be $50\sqrt{5} = 112$ meters per coordinate, assuming no additional human error. Typically plotting errors in the range of 100-200 meters were noted.

(2) The second method is semi-automatic and uses a desk type electronic calculator with the incorporation of a correction for mask angles.

In this method, backtrack firing point positions were calculated using a Wang Model No. 700A. The formulas used are:

$$X_F = R_1 \mathrm{SIN} A_1 - 1/2 \; \frac{\left(R_2 \mathrm{SIN}\, A_2 - R_1 \mathrm{SIN}\, A_1\right)}{N - 1} - \frac{0.21\left(R_2 \mathrm{SIN}\, A_2 - R_1 \mathrm{SIN}\, A_1\right)}{T^2}$$

$$(R_1 \,\mathrm{TAN}\, \phi - \Delta H)$$

$$Y_F = R_1 \mathrm{COS} A_1 - 1/2 \; \frac{\left(R_2 \mathrm{COS} A_2 - R_1 \mathrm{COS} A_1\right)}{N - 1}$$

$$- \frac{0.21 \left(R_2 \mathrm{COS} A_2 - R_1 \mathrm{COS} A_1\right)}{T^2} \quad (R_1 \mathrm{TAN}\, \phi - \Delta H)$$

where

R_1 is first range

A_1 is first azimuth

R_2 is last range

A_2 is last azimuth

ϕ is mask angle

ΔH is radar HT - weapon HT at first detection

N is no. blips

T is a corrected time between first and last looks:

$$T = 2(N - 1) + \frac{A_2 - A_1}{3200}$$

Annex D gives the Wang program which was implemented to solve the above equations. The last term for X_F and Y_F above are mask angle corrections. The most important feature in using machine assists is that the additive error of the procedure is zero unless an error is made in the entry of a number. Another feature is the ease and speed and the elimination of plotting and reading map values.

A miniature Hewlett Packard calculator (HP-35) was also used to compute firing points and is believed to be a valuable time saving asset for such application. See Appendix 1, Annex D, this report for HP-35 program.

f. There are three prime contributors to the backtrack prediction error: Antenna speed variation, range error and azimuth angle error.

(1) Antenna speed variations are most likely to be caused by wind which results in an effect that repeats each 360°. This would have virtually no effect on either the backtrack or mask angle corrections. If the antenna ran at the wrong speed continuously the effect on backtrack would be self-cancelling because the backtrack would now be based on the new spacing between the blips; however, the mask correction would suffer. Typically, for a speed error of 10%, which is unlikely, and 10 blips and a masking situation leading to a 300 meter correction, the error will be about 60 meters; however it is not suspected that speed error was signficant for these tests.

(2) In the 24 km range mode, the range gate width is 462 meters. Since the transmitted pulse is relatively narrow (approximately 100 meters wide) little gain is achieved by gate splitting; and the peak system range error is approximately 231 meters. A variable which is uniformly distributed between specified peak values has a standard deviation of $\beta/2\sqrt{3}$, where β is the peak to peak value of error. For this case, the standard deviation is:

$$\sigma = \frac{462}{2\sqrt{3}} = 133 \text{ meters RMS}$$

Thus, range error may be considered to have a one-sigma value of 133 meters and a probable error of approximately ±115 meters.

(3) Although no conclusive data is available, a probable readout error of ±0.5 degree is assumed to exist resulting from system non-linearities, and operator readout error; however, the Fort Sill data shows the possibility of readout errors nearly an order of magnitude greater which may be due to different operators aligning the electronic strobe line to different edges of the target point. It had been observed that under some conditions the strobe was placed at the lagging edge of the target paint instead of the leading edge. A study of the polar plots shows the amount of azimuth off. This situation can be observed in Fort Sill test 5 Seq 3, Test 7 Seq 3, Test 7 Seq 4, Test 13 Seq 3, and Test 15A Seq 2, which show strong biases to one or the other side of the correct azimuth angle. See Appendix 1, Annex F this report for polar plots.

g. Another factor that is considered to be most important in backtrack computations is mask angle corrections.

It has been recognized that a potential improvement in backtrack results is possible by correcting the computation of firing point arrived at in paragraph e.(1) above, according to the mask angle (elevation angle to a terrain feature) if any, which exists in the vicinity of the first sighting. The mask angle from the radar is determined by observing whether the computed firing point is in a clear line of sight from the radar or masked by a terrain feature of a determinable height. A close approximation to a parabolic correction was then computed for each corrected firing point axis (S_X and S_Y) equal to:

$$S_X = \frac{0.21\,(X_2 - X_1)\,(R_1 \text{ TAN } \phi - \Delta H)}{T^2}$$

$$S_Y = \frac{0.21\,(Y_2 - Y_1)\,(R_1 \text{ TAN } \phi - \Delta H)}{T^2}$$

where

ϕ is the mask angle and

ΔH is the height of radar minus the height of the backtracked point.

The results of applying mask angle correction to the operator manual map plotted firing points showed an average improvement of 37.1 percent in virtually all cases of mask angle as tabulated below. Further mask angle correction showed a marked improvement as the mask angle increased. (See Table I).

h. Dahlgren Tests - The AN/TPQ-31 arrived at Dahlgren on 20 November 1972 and was fired up and operated at the main range site until 29 November. Targets of opportunity were used during this period to familiarize the operators with the operation of the radar system. The firings at Dahlgren were primarily used for equipment performance checkout and operating procedures refinement. Therefore, only the firings where data of significant nature was collected have been processed, namely, firings on 6 and 7 December. Firing data collected on the other dates are included in this report for record purposes. The firings where the radar painted a high frequency of prints, and where data (such as location of firing point, type of weapon, and QE were provided) was considered significant enough to be processed.

(1) The firing data collected at Dahlgren is contained in Annex E which addresses the reduction of the data collected on 6 and 7 December. The firings on these dates were divided into four groups depending on their QE, and then miss distances were computed. For the 59 rounds processed, with bias removed, a CEP of 105.2 meters was attained on a 81 mm mortar located approximately 6830 meters from the radar.

EFFECT OF MASK ANGLE CORRECTION

Test No.	Weapon	Mask 1 Deg Map	(No. Mask Angle Corr.) Plotted Miss Dist.	(Included Mask Corr.) Machine Miss Dist.	% Improvement
5/1	105 mm How	1	1293 meters	537 meters	59.5%
5/2	105 mm How	1	-	-	-
5/3	105 mm How	1	1693	1173	30.8%
5/4	105 mm How	1	2163	787	63.7%
5/5	105 mm How	1	1106	230	79.3%
7/1	105 mm How	1	1015	836	17.7%
7/2	105 mm How	1	880	630	28.5%
7/3	105 mm How	1	1316	820	37.7%
7/4	105 mm How	1	2008	1584	21.2%
8	155 mm How	1	1030	449	56.5%
11/1	105 mm How	0.5	955	867	9.3%
11/2	105 mm How	0.5	3741	3032	19.0%
12/1	105 mm How	1	1700	1324	22.2%
12/2	105 mm How	0.5	950	532	44.0%
13/1	155 mm How	0.2	680	591	13.1%
13/2	155 mm How	0.2	440	332	24.[illegible]
13/3	155 mm How	0.2	450	467	-
16/1	8" How	0.5	-	-	-
16/2	8" How	0.5	416	136	67.4
					37.1%

Table I

(2) During the Dahlgren test program, the radar functioned exceptionally well. A few minor problems were experienced, but none affected the operational readiness of the radar. The operational performance during the actual firings was 100%. It is to be noted that the antenna pedestal of the radar had accumulated 3,000 hours of life test prior to being deployed to Dahlgren.

i. Forts Sill Tests - The firings at Fort Sill began on 23 January 1973 and ended on 7 March 1973. Each firing consisted of a number of sequences, with a specified number of rounds fired during each sequence. Data on firings 2 through 18 were collected with the AN/TPQ-31. The weapons used during these firings consisted of the 81 mm and 4.2 mortars, the 105 mm, 155 mm and 8.0" howitzers and a 175 mm gun. Predicted firing points were derived from the collected data. See Annex F of this report for analysis of data.

(1) The values of accuracy for the predicted firing points were processed at the radar site manually and later by machine. It is difficult to compare both methods, in that, the true firing points used, for computation, were different for each of the methods. The accuracies indicated for the types of weapons, by each method against its assumed true firing point, are as follows:

OPERATOR CALCULATED

Weapon	No. Rounds (Detected)	Avg. Miss Distance All Rounds	No. Sequences (Detected)	Miss Distance Best Round each Sequence	Miss Distance Best One Round
81 mm	20	237 m	2	90	80
4.2 mm	86	498 m	17	369	20
105 mm	160	1538 m	18	770	100
155 mm	46	431 m	7	270	20
8"	23	720 m	2	240	140
175 mm	10	280 m	1	140	60

MACHINE CALCULATED

Weapon	No. Rounds (Detected)	Avg. Miss Distance All Rounds	No. Sequences (Detected)	Miss Distance Best Round each Sequence	Miss Distance Best One Round
81 mm	20	244 m	2	150	148
4.2 mm	86	601 m	17	487	51
105 mm	160	1252 m	18	655	135
155 mm	46	331 m	7	259	67
8"	23	476 m	2	312	93
175 mm	10	155 m	1	128	128

(2) The machine calculated firing point accuracies can be further refined by screening out non-valid erroneous tracks such as on weapons firing from points not associated with the test program. In eliminating these tracks, the predicted firing point accuracies listed below were attained. See Appendix 2, Annex F, this report, for further discussion on erroneous tracks.

Weapon	No. Rounds (Detected)	Avg. Miss Distance All Rounds	No. Sequences (Detected)	Miss Distance Best Round each Sequence	Miss Distance Best One Round
81 mm	20	244	2	150	148
4.2"	86	601	17	487	51
105 mm	144	905	15	415	135
155 mm	42	320	7	259	67
8"	23	476	2	312	93
175 mm	10	155	1	128	128

(3) The firing sequences explored the capability of the system beyond as well as within the designed operating limits. Unfortunately, a very high percentage of the rounds were fired at QE's that placed their track above the antenna

beam, at velocities that fell in the blind speed notch, and at distances where the size of the target was not compatible with the detection range of the radar. A situation could have prevailed where all the rounds were out of the AN/TPQ-31 antenna beam and also in its blind speed notch, wherein very little data would have been collected. In this context the 105 mm sequences were examined and fell into five categories:

(a)	Rounds not detected (radar inoperative)	1
(b)	Valid rounds (correct projectile tracked) initial velocity of trajectory detectable	4
(c)	Valid rounds, but initial velocity of trajectory not detectable	10
(d)	Valid rounds, but trajectory above beam and initial velocity not detectable	7
(e)	Questionable rounds (wrong velocity for scheduled refereces) see Appendix F-2-1	1

Thus, four out of 23 of the 105 mm howitzer sequences are expected to yield meaningful results, mainly because of the crucial dependence on seeing the initial part of the trajectory. This helps account for the poor results of the 105 mm rounds where only tests 7/1, 7/3, 9/2 and 10/1 wer usable rounds within the radar design parameters. Considering these sequences, the average miss distance for the 105 mm rounds becomes 733 (4 sequences) meters vice 1139 meters (22 sequences).

(4) The AN/TPQ-31 has the capability for detecting projectiles fired anywhere within 24 km provided that various parameters of the round fall within the design ratings of the radar. The probability that a "detectable" round is actually detected is a significant performance indication. This probability is available from the accumulated data by noting which rounds had detection curves which did not break through the threshold <u>at any point</u>. The reasons for this are examined in Appendices 3 and 4, Annex F but generally the projectile may have been in the blind velocity notch, or was too distant, or too high above the radar beam. Also, those rounds for which the radar was inoperative are not counted here.

Total No. of Theoretically Detectable Rounds Fired	353
Total No. of Above Rounds Seen	306
Probability of Detection of all "Detectable" Rounds for All Fort Sill Data	$\frac{306}{353} \times 100 = 87\%$

Actual detection without regard for theoretical detectability on each weapon was shown to be:

Weapon	Sequence with Detections	Rounds Scheduled	Rounds Detected	Rounds Missed (No. Detec.)	Rounds Missed (Radar Problem)	% Detected*
81 mm	2	20	20	-	-	100
4.2"	17	178	86	9	83	90
105 mm	18	263	160	80	23	67
155 mm	7	54	46	-	8	100
8"	2	50	23	27	-	46
175 mm	1	73	10	55	8	15

*Percentages do not reflect rounds missed due to radar problems.

The worst case was the 175 mm gun which, due to its high muzzle velocity and long range, placed shells too high for the beam, too distant or in the blind speed notch on numerous firings.

(5) Apart from the problems recorded on data sheets in Appendix 5, Annex F, the AN/TPQ-31's performance record was satisfactory. It is difficult to foresee a problem such as the one experienced with the antenna. It had accumulated 3500 hours of fail-free operation at the time the problem was encountered. It is also felt that the Short Range Console problem would not have occured had more reliable power generators been available.

3. CONCLUSIONS

a. The majority of rounds fired during the tests were outside the designed operating limits of the AN/TPQ-31.

b. The following processing and/or inherent system errors can adversely affect weapon firing point determinations:

(1) Manual plotting technique errors	112 meters per coordinate
(2) Probable range error	±115 meters
(3) Probable azimuth error	±0.5 degree

c. Under the prevailing test conditions the AN/TPQ-31 attained the following firing point accuracies and percent of detections:

Weapon	No. Rounds	Miss Distance	% Detection
81 mm	59	105 meters (Dahlgren)	100
4.2"	178	542 meters (Fort Sill)	90
105 mm	263	956 meters (Fort Sill)	67
155 mm	54	361 meters (Fort Sill)	100
8"	50	476 meters (Fort Sill)	46
175 mm	73	155 meters (Fort Sill)	15
81 mm	20	244 meters (Fort Sill)	100

d. When applicable, the introduction of mask angle data into the back track computations significantly improves the accuracy of predicted firing points.

e. The bias errors resulted primarily from an inability to accurately bore-sight the radar antenna during azimuth orientation.

f. The AN/TPQ-31 detection performance was very successful against mortar type rounds, for which it was designed, and it had a limited detection success against artillery type rounds.

g. The data collected in this report is suitable as a basis for developing a Field Test Plan for evaluation of the AN/TPQ-31( ).

4. RECOMMANDATIONS

a. That the data in this report be used as a basis for developing the AN/TPQ-31( ) Field Test Plan.

b. That the majority of rounds to be fired during the field test of the AN/TPQ-31( ) be scheduled to fall within its design limits in order to provide a meaningful evaluation.

c. That a boresight telescope be provided in order to permit accurate azimuth orientation which will help reduce the high frequency of bias errors encountered during the firings.

d. That survey data on the true location of the firing weapons during AN/TPQ-31( ) field evaluation be made readily available to the test team upon completion of each firing sequence.

Annex A - (AN/TPQ-31 Equipment Characteristics - Radar Performance Parameters) to Report of AN/TPQ-31 Performance during Evaluation as a Hostile Weapon Locator

AN/TPQ-31 RADAR SET EQUIPMENT CHARACTERISTICS

SYSTEM CHARACTERISTICS

1. Total weight, Radar Set AN/TPQ-31:
   a. Shelter: 3256 lbs.
   b. Helicopter transport pallet A: 977 lbs.
   c. Helicopter transport pallet B: 1515 lbs.
2. Shelter volume: 515 ft^3
3. Input power requirements:
   a. With air conditioners: Three-phase, four-wire, 400 Hz, 208/120-volts, 25-kW, power factor - 0.9 lagging.
   b. Without air conditioners: Three-phase, four-wire, 400 Hz, 208/120-volts, 10-kW, power factor - 0.9 lagging.

ANTENNA

1. Type: Cosecant-squared.
2. Dimensions:
   a. Horizontal aperture: 15 feet, 9 ± 2 inches.
   b. Vertical aperture: 6 feet ± 2 inches.
3. Beamwidth:
   a. Horizontal: 3.7 degrees.
   b. Vertical: 11 degrees.
4. Sidelobe and back radiation:

	Side	Back
Azimuth	25 dB	30 dB

ANTENNA (Cont.)

5. Gain

   a. Greater than 27 dB over a frequency range of 1300 to 1350 MHz.

   b. Not less than 26 dB over a frequency range of 1250 to 1300 MHz.

6. Scan rate:

   a. Azimuth: 30 rpm

   b. Elevation: Tilt -2 to +5 degrees (manual adjustment).

7. Drive system:

   a. Continuous search operation: Servo-operated dc motor through a gear train having a reduction ratio of 233.3 to 1.

   b. Manual searchlight operation: Manual rotation of handwheel.

RADAR TRANSMITTER T-1111/TPQ-31

1. Frequency Range: 1250 to 1350 MHz.

2. Wavelength:

   a. 24 cm at 1250 MHz

   b. 22.2 cm at 1350 MHz

3. Transmitter and duplexer tube types:

   a. TR (V1851 type 7166/MA 3770) and ATR (V1852, V1853, and V1854 RCA type 8270926-1) gas-filled tubes in duplexer.

   b. Magnetron (V204 type QK 358), gas-filled thyratron (V201 type HY-15), hard vacuum diode (V203, type 561), and gas-filled diode (V205, type KU52).

4. Average power: 1.0 kW nominal

5. Peak power: 1.0 MW nominal

RADAR TRANSMITTER T-1111/TPQ-31 (Cont.)

6. Pulsewidth:

    a. 0.7 microseconds at 1600 PRF

    b. 4.2 microseconds at 267 PRF

7. Pulse repetition rate frequency: 1600 or 267 pulses per second (pps)

8. Power requirements for operation:

    a. Input system trigger: 40-V, positive pulse

    b. Filament voltage: 6.3 Vac

    c. Magnetron filament transformer: 130 Vac

    d. Magnetron tuning: 28 Vac

    e. Pulse generator: 350 Vdc

    f. High B+: 1000 Vdc

    g. Magnetron modulator plate power: 8500 Vdc

RADAR RECEIVER R-1585/TPQ-31

1. Stalo, five crystal-controlled frequency channels

2. Noise figure (including duplexer): 9 dB

3. Intermediate frequency: 30 MHz

4. IF bandwidth:

    a. 1.5 MHz in the 20- and 40-mile ranges

    b. 0.45 MHz in the 275-mile range

    c. 1.5 MHz in the HFSR mode

5. Normal video minimum discernible signal (mds): 104 dBm minimum

6. Coherent video minimum discernible signal (mds): 100 dBm minimum

INDICATORS

1. Azimuth-Range Indicator IP-954/TPQ-31

    a. PPI scope: 10-inch crt, type 10WP7

    b. A-scope: 3-inch crt, type 3SP1

    c. Range scales: 20, 40, and 275 miles

2. Azimuth-Range Indicator IP-953/TPQ-31

    a. PPI scope: 16-inch crt, type 16M59P33M

    b. Range scales: 0 - 12 and 0 - 24 km (1.54 - 6.47 and 0.54 - 12.95 nmi)

SIGNAL DATA CONVERTER-SYNCHRONIZER CV-2578/TPQ-31

1. Range-gated doppler processor
2. 52 range-gated signal detectors
3. Synthetic video outputs to both indicators

AN/TPQ-31 RADAR PERFORMANCE PARAMETERS

RADAR SENSITIVITY

The received signal to noise ratio of a radar target observed for T_o sec is:

$$\text{REC SNR} = \frac{(P_{TR\text{-}PK})\ \tau\ (PRF)\ G^2_{ant}\ \lambda^2\ T_o\ \sigma_T}{(4\pi)^3\ R^4\ KTF\ L_R L_T}$$

If the required detection SNR is S, and processing loss is D, (departure), then

$$\text{REQ REC SNR} = (S)\ (D) \text{ for detection}$$

Solving for target size:

$$T = \frac{(S)\ (D)\ (4\pi)^3\ R^4\ KTF\ L_T L_R}{(P_{TR\text{-}PK})\ (\tau)\ (PRF)\ G^2\ \lambda^2\ T_o}$$

	-	+
S (Prob Det = 0.8, 1 F.A. per scan)		11.1 dB
KT	204	
F (9 dB assumed)		9
G^2_{ant} (G = 27.5 dB)	55	
λ^2 (λ = 23 cm)		12.6
$(4\pi)^3$		33

	-	+
R^4 (R_{max} = 24 Km)		175.2
$L_R L_T$		2
P_{TR} (10^6W)	60	
τ (0.7×10^{-6})		61.55
PRF	32.05	
T_o (21 millisec)		16.8
D		11.5

$L_{(i)}$ = -4.5 dB (int loss for 33 hits)

Non-ideal RC = -1.0 dB

Rg Loss = -4.5 dB (range gate straddle and mismatch)

Quadrature Loss = -1.5 dB

-11.5 dB

Total = -18.3 dB = σ_T

σ_T = 0.015 sq meters @ 24 Km

The radar cross sections (RCS) of various projectiles from 81 mm to 155 mm have been found to average about 0.018 sq meters. Applying a case I fluction loss (at Pd = 0.8) of -5 dB gives an equivalent size of nominally 0.005 sq meters required for satisfactory detection sensitivity.

Assuming all radar parameters at the design value, and a target on the nose of the beam, the maximum detection range for a 0.005 sq meter target is

$$R = \sqrt[4]{\frac{0.005 \text{ sq m}}{0.015 \text{ sq m}}} \times 24 \text{ Km} = 18.6 \text{ Km (see fig. 1)}$$

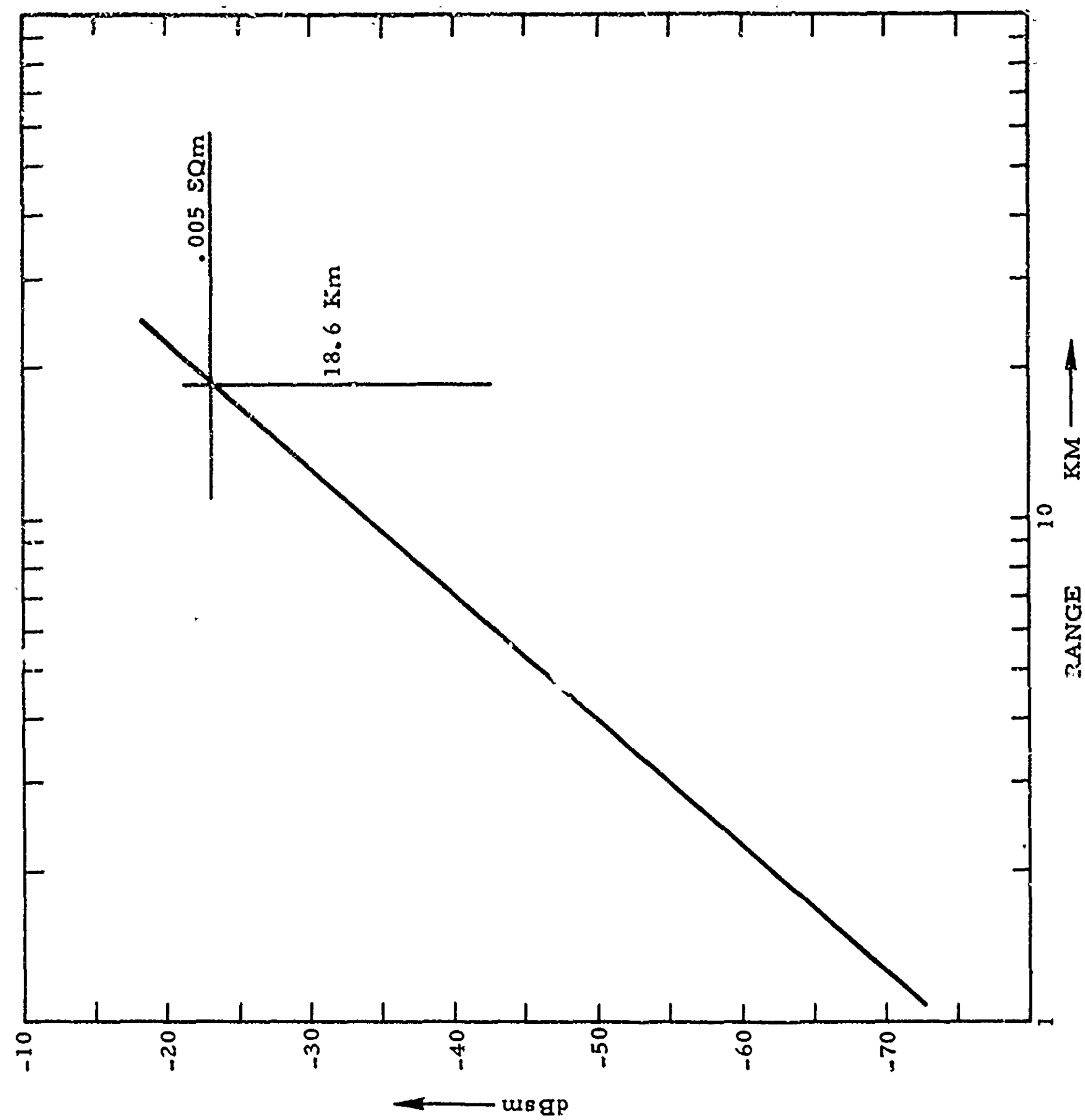


Figure 1. AN/TPQ-31 MDS vs. Range

Antenna Pattern

Fig. 2 shows the vertical gain for various degrees of antenna tilt. Fig. 3 shows the coverage for a target of 0.005 sq meters based on the above pattern and the system parameters presented earlier.

Velocity Notch

Fig. 4 shows a plot of velocity notch versus speed. As is characteristic of single PRF doppler radars, doppler velocities at or near multiples of the PRF are attenuated by the clutter filter. The amount of attenuation is a function of velocity and may be read directly from the plot of Fig. 4. The wide notch is used for particularly severe clutter or weather.

Sensitivity vs Time Control (STC)

STC is a technique to reduce the system gain for targets at short range to reduce the effect of clutter which is most bothersome at low ranges. The STC gain variation produces most attenuation (60 dB) at zero range and is reduced by approximately the fourth function of range until full gain is achieved at about 6 Km. The effect of STC, when considering a target in the maximum gain portion of the beam, is to hold the required minimum target to an approximately constant value while cutting clutter by an amount which is an inverse function of range. However, a shortcoming is that most desired targets which are at short range are also at high angles where the beam coverage has low gain. The STC in this case only makes matters worse.

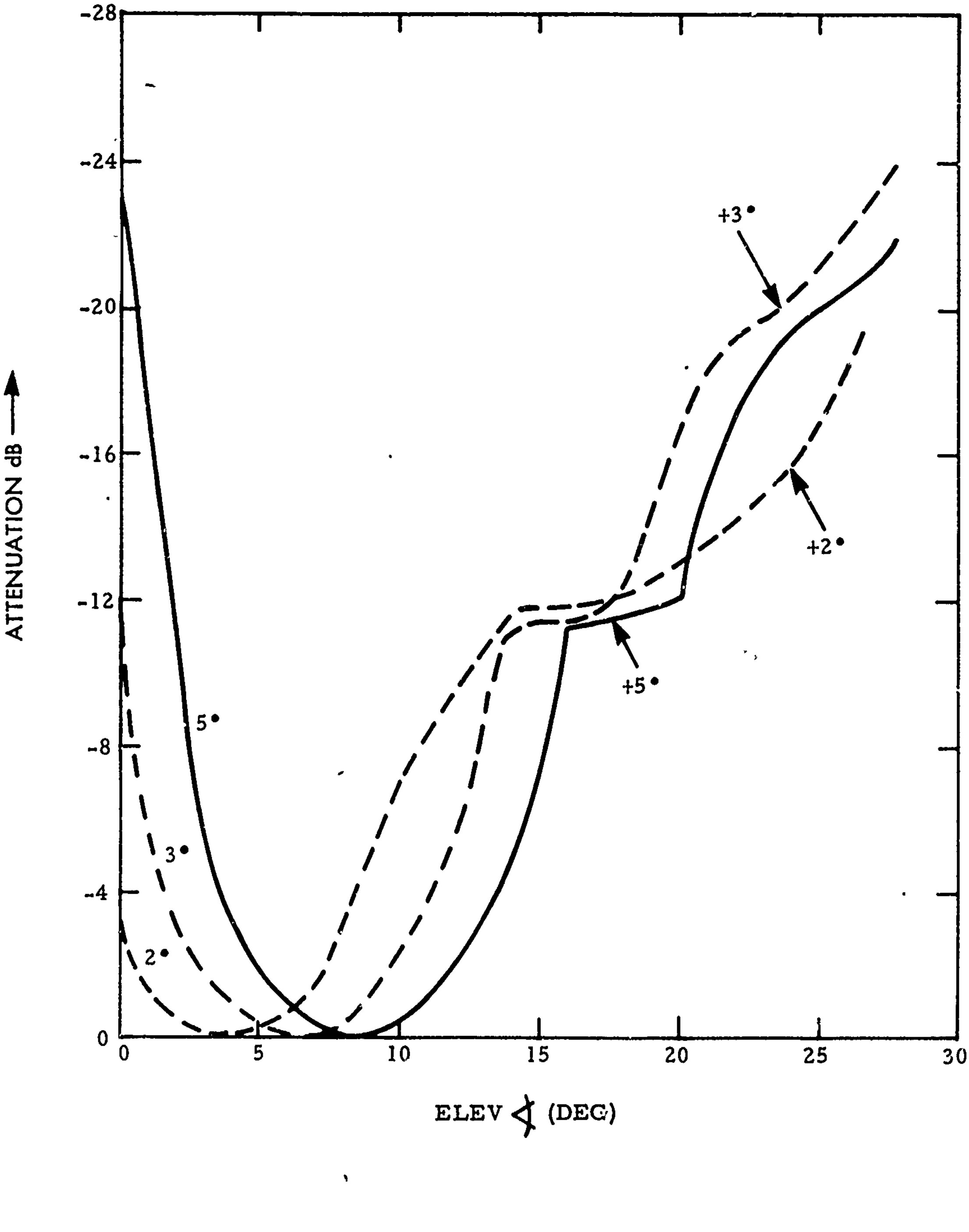


Figure 2. AN/TPQ-31 Antenna Vertical Pattern

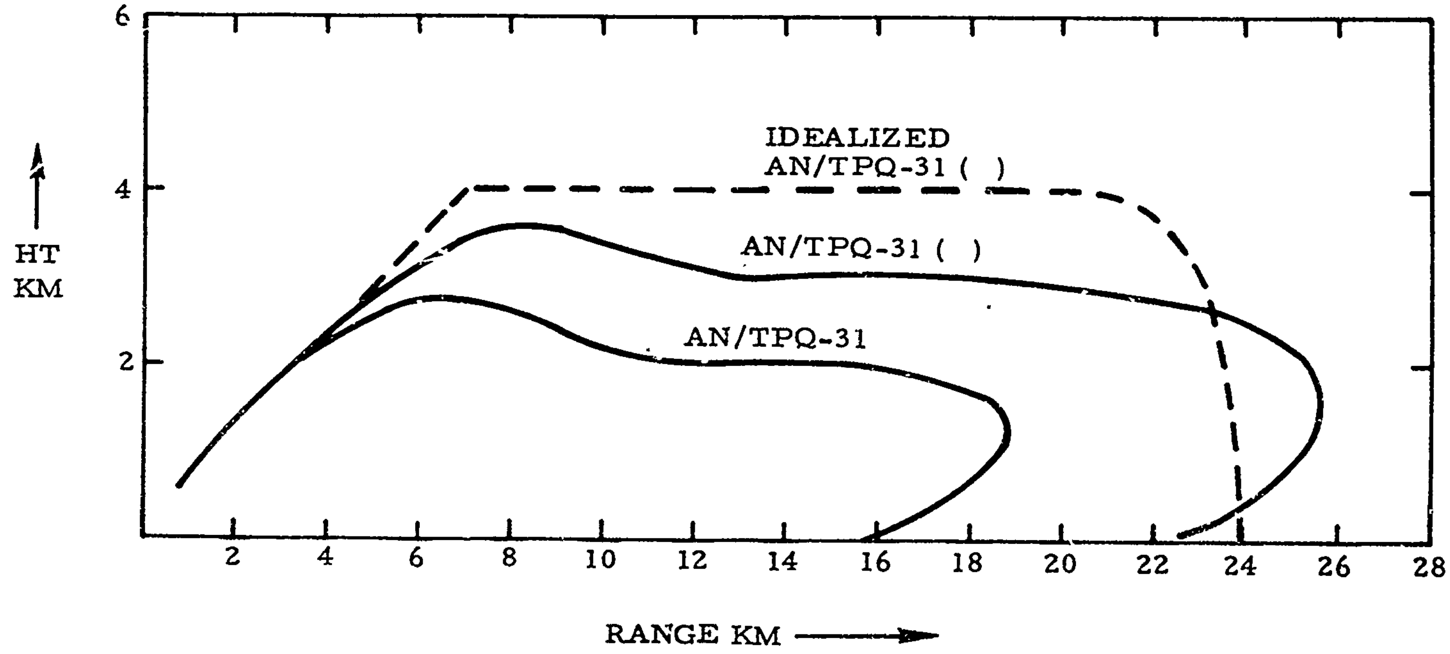


Figure 3. Radar Coverage for σ_T = 0.005 sq meter (no STC)

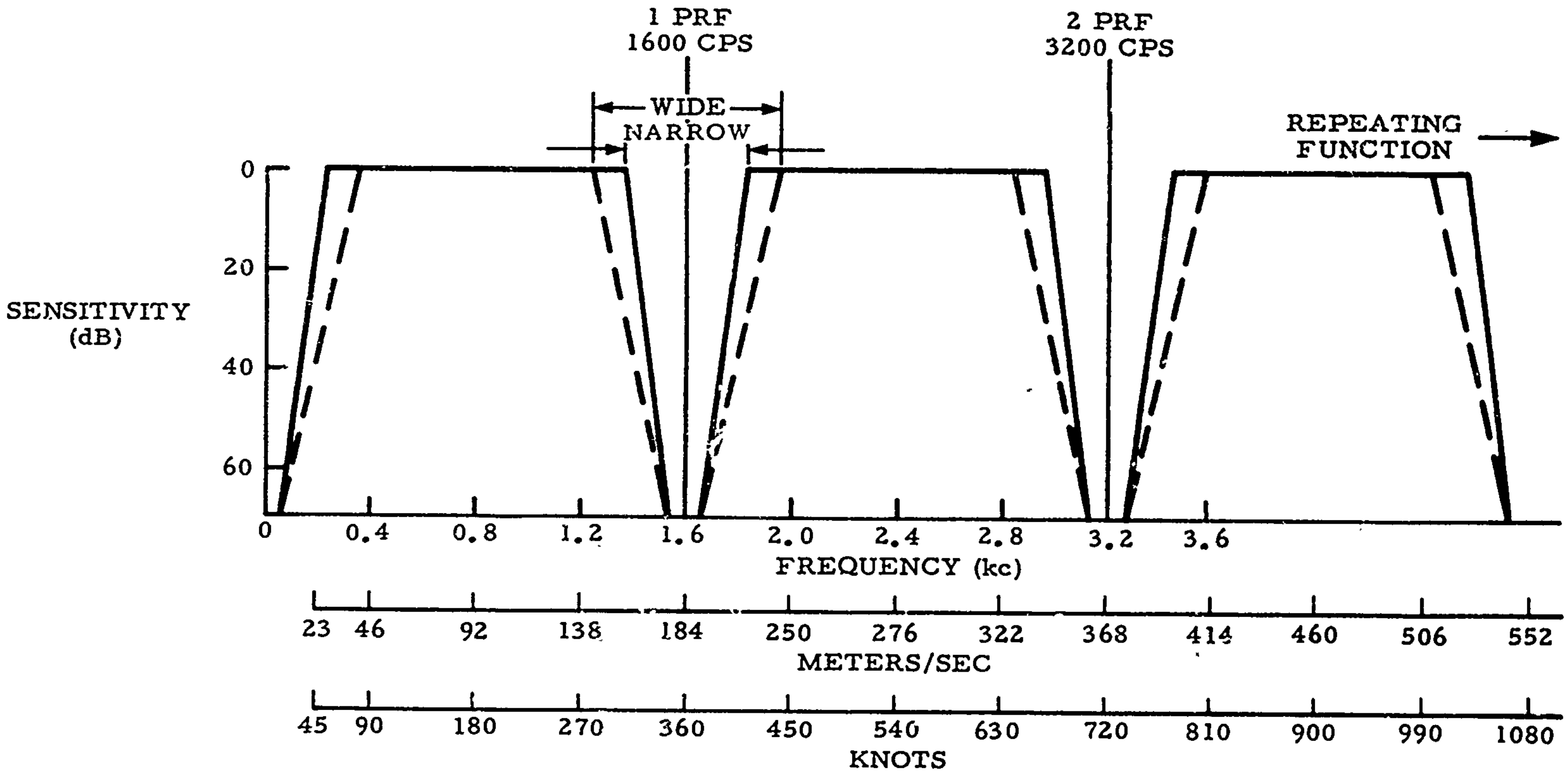


Figure 4. AN/TPQ-31 Velocity Response Characteristic Curve

Annex B - (Background Information) to Report of AN/TPQ-31 Performance during Evaluation as a Hostile Weapon Locator

BACKGROUND INFORMATION

In May 1967 the United States Marine Corps, to meet an urgent Vietnam requirement for a 360° counter mortar radar capability, awarded Raytheon a contract to test the basic capability of the AN/UPS-1 air search radar and evaluate its potential in a two dimensional mortar detection role. The test and evaluation program was undertaken at the Marine Corps Development Center, Quantico, Virginia and the basic capabilities and deficiencies of the AN/UPS-1 radar were established. The result of these tests showed a definite capability of the radar to provide the basic functions required to fulfill the new mission. In October 1967 Raytheon received a quick reaction contract from the USMC for the development of 10 AN/TPQ-31 2D counter weapon radars, the first to be delivered for test in 9 months. In order to provide AN/TPQ-31 equipment in Vietnam in the minimum possible time, existing AN/UPS-1 air search radars, developed during the mid 1950's, were provided from available Marine Corps assets for modification. Further, because of the time restrictions, only those modifications essential to the basic function of the AN/TPQ-31 were undertaken. Various features which may have been incorporated in a complete "design-for-the-purpose" were of necessity not pursued. The major modifications made to the 12 year old design of the AN/UPS-1 in 1967, to develop the AN/TPQ-31, were limited to the following:

Transmitter: Increase PRF to avoid blind speeds associated with mortar rounds. Increase output frequency stability and decrease time jitter to improve SCV.

Receiver: Modify stalo and coho for improved SCV.

Indicator: Provide 16" PPI with selectable 24 KM and 12 KM ranges.

MTI: Replace MTI delay line with a range gated doppler processor to provide synthetic video to the PPI indicator and further improve SCV.

In June of 1968, the AN/TPQ-31 system was tested at Camp Lejeune, North Carolina. Analysis and evaluation of the test results confirmed that the desired capabilities were successfully incorporated into the AN/TPQ-31. The tests performed at Camp Lejeune were similar to those conducted with the AN/UPS-1 at Quantico except they were more detailed in nature and extensive in scope. In addition to demonstrating its ability to acquire and track mortar shells, the tests were extended to include howitzers and guns with emphasis placed on the radar's ability to determine the source of hostile firing with sufficient accuracy to permit direct assignment of retaliatory action without the use of other precision tracking devices.

Results of the tests were highly gratifying because the demonstrated capability significantly exceeded the performance specifications, despite the fact that the design was based on the mortar threat only. Helicopter gun ships were directed by the radar operator in simulated counter strike operations. The location accuracy obtained was generally better than ± 250 meters. No significant terrain features were encountered at Camp Lejeune, the firing range was generally flat, therefore possible mask angles were very small. The firing points and impact area were visible to the radar and the clutter from trees presented no problem to the radar.

In September 1968 the first units were deployed in Camp Pendleton, California and active training of operator and maintenance crews commenced. The terrain at Camp Pendleton is generally mountainous and significant mask

angles were encountered. However, although this presented problems in predicting the actual position of the weapon firing from defilade positions, the results in these adverse circumstances were considered of real value. Various methods of extrapolating the observed projectile track back to the point of origin were developed but none were implemented as a formal procedure. In February of 1969 deployment of active units commenced in Vietnam. The initial locations were: (1) Southwest of DaNang at Hill 55, (2) Northwest of Dong Ha at Fire Base C2, 7 KM from the DMZ and (3) in Saigon. The Saigon operation was not successful because the radar had to compete with excessive clutter returns from local buildings, etc. and the targets were not always detected. The site was on top of one of the tallest buildings in the city - while this would appear to be a vantage point - it was in fact a serious disadvantage because the high clutter returns could not be masked from the radar. Brief deployment outside the city at ground level produced more satisfactory results and the radar was later moved to LZ Sharon East of Dong Ha. Of the various systems ultimately deployed in combat locations, the best results were obtained from Hill 55, Da Nang and Fire Base C2 Dong Ha, partly because the enemy was particularly active in these areas. Careful siting of the radar system and constant vigilance on the part of the radar operator were found to be essential to the effectiveness of the system.

Annex C - (AN/TPQ-31 ( ) Performance Objectives) to Report of AN/TPQ-31 Performance as a Hostile Weapon Locator

Raytheon, under Contract No. M00027-72-C-0098 with the U.S. Marine Corps, is conducting a modification program to further enhance the existing performance and versatility of the current models of the AN/TPQ-31 Radar System. Under this program the following desired design objectives are being pursued.

AN/TPQ-31 ( ) PERFORMANCE OBJECTIVES

Description	Objectives
A. Environmental	Allow 20% degradation in 4 mm/m of rain. Operate at sea level to 3000 m. alt.
B. Reliability	90% Prob. of operating 24 hr/day for 30 days. Down time 1 hr/day.
C. Prob. Detection and Location (0.0014 sq. meters at 25 Km)	80%
D. Accuracy:	
1. Cannon Location	100M c.e.p. for 10 Km weapon at QE 200 Mils. to 150M c.e.p. for 20 Km weapon QE 300 Mils.
2. Rocket Location (122 mm or greater)	100M c.e.p. or c.e.p. = 1% range (whichever is greater) for QE - 400 Mils.
3. Mortar Location (60 mm or greater)	80M c.e.p. for 10 Km weapon at QE 1000 Mils 90% within 160M at 12 Km range.

Description	Objectives
E. One Round Location	Yes
F. Radar-Weapon Operating Range	
1. Howitzer, 75 mm and 105 mm	1-25 km
2. Howitzer, 155 mm	1-25 km
3. Gun, 175 mm	1-25 km
4. Rockets (122 mm)	1-25 km
5. Rockets (200 mm)	1-25 km
6. Mortar (60 mm)	0.5-25 km (QE = 1000 Mils)
G. Enemy Weapon Characteristics and Conditions	
1. Max. Projectile Velocity	1000 m/sec from 5 km to max. ranges and 500 m/sec from 0.5 to 5 km
2. Minimum Weapon QE for Cannon and Rocket	300 Mils from 10 km to max. ranges in (F.) and 200 Mils from 2 to 10 km.
3. Weapon QE for Mortar	500 Mils to 1500 Mils.
4. Terrain Masking of weapon at radar	-50 Mils to +200 Mils.
5. Radar-Weapon Aspect Angles	0 Mils to 1600 Mils.
6. Radar-Weapon Height Differential	0 to ± 1000 Meters
H. Sectors of Search Track	
1. Simultaneous Search and Locate	360° to 25 km range
I. Adjustment of Artillery	
1. Fire-for-Effect Missions	Yes

Description	Objectives
2. Firing Corrections by Registration	Yes
J. Reaction (i.e., set-up time from start of Off-load to Operational)	
1. System not emplaced	30 mins.
2. System moved by air	1 hour
3. Displacing	15 mins.
K. Mobility, tracked or wheeled vehicles. No degradation of vehicle fording or swimming capability.	Yes
L. Presentation	
1. Automatic Print-out of hard copy:	Yes
a. Weapon Loc. in UTM cords	Yes
b. Weapon Traj. back azimuth	Yes
c. Time of Location	Yes
d. Identity of radar	Yes
e. Altitude of weapon locat.	Yes
f. Indicate whether weapon is cannon or rocket launcher	Yes
2. P.P.I. Az. vs Range	Yes

	Description	Objectives
M.	Orientation	
	Rapid visual or electronic means of orienting the radars will be provided.	Yes
N.	Rate of computing weapon locations	4 per min.
O.	Air portability via C-130 and Helicopter Air Lift	Yes
P.	Surface Transportability by Truck or Track Vehicles	Yes
Q.	Number of simultaneously-firing weapons which can be located	10
R.	Manual (back-up) Method of Weapon Location	Yes
S.	Other Capabilities	
	1. Ability to choose between weapons. That is, select a new, previously unlocated weapon in each of 3 batteries rather than 3 weapons in one battery.	No
	2. Provide historical information on activity of located weapon.	No
T.	Storage under extreme conditions without subsequent perf. degradation.	1 year
	1. Time to restore radar to full capability.	8 hours
U.	Total life expectancy	10 years

PHYSICAL CHARACTERISTICS

Description	Objectives
A. Design Considerations	
1. No. of vehicles required	2
2. Emplace and operate on 10° slope	Yes
3. Adequate shelter for operator, comm. equip., plotting board, etc.	Yes
4. Provision for remote operations	100 ft.
B. Weight	
1. Curb weight	4,500 lbs.
2. Combat loaded	5,000 lbs.
C. Configuration:	
1. Operational height	168"
2. Surface mobility	
a. Railway height	92"
b. Highway and cross country height	114"
c. Width	106"
3. Dimensions to conform to Berne International clearance diagram	Yes
4. Air Portability:	
a. Height	102"
b. Width	106"
D. Other Requirements	
1. Withstand exposure to normal ocean beach atmosphere	3 months
2. Fungus-Proof in operating and transport configuration	Yes

Appendix 1 - (Comparison of AN/TPQ-31 ( ) to AN/TPQ-31) to Annex C of Report of AN/TPQ-31 Performance during Evaluation as a Hostile Weapon Locator

AN/TPQ-31 ( ) COMPARISON TO AN/TPQ-31

Coverage

The increased sensitivity of the AN/TPQ-31 ( ) due to higher average transmitter power, more sensitive received and better processing leads to the coverage pattern for a 0.005 sq meter target shown in figure 1. The AN/TPQ-31 ( ) improvement is conservatively +7 dB and would have allowed at least some detections for tests 14, 15/1, 15/2 and 16/1 at Ft. Sill which were beyond the range of AN/TPQ-31.

Velocity Notch

The AN/TPQ-31 ( ) is designed for a PRF of 6000 Hz which places the first blind velocity at 4 times the value for the AN/TPQ-31. Thus the numerous cases, such as tests 7/2, 7/4, 9/3, etc. at Ft. Sill, where the radar was blind to the shell at the start of the trajectories, would have been properly tracked. Successful track, from the point the s rises above the radar horizon, is necessary for minimum miss distance. None of the many cases of velocity notch blindness (see detection curves, Appendix 3, Annex F) for the Ft. Sill tests would have presented a blind condition for the AN/TPQ-31 ( ).

Detectability

Based on the relative coverage and velocity notch improvement of the AN/TPQ-31 ( ) over the AN/TPQ-31, virtually all of the Ft. Sill firings would have been detected by the AN/TPQ-31 ( ).

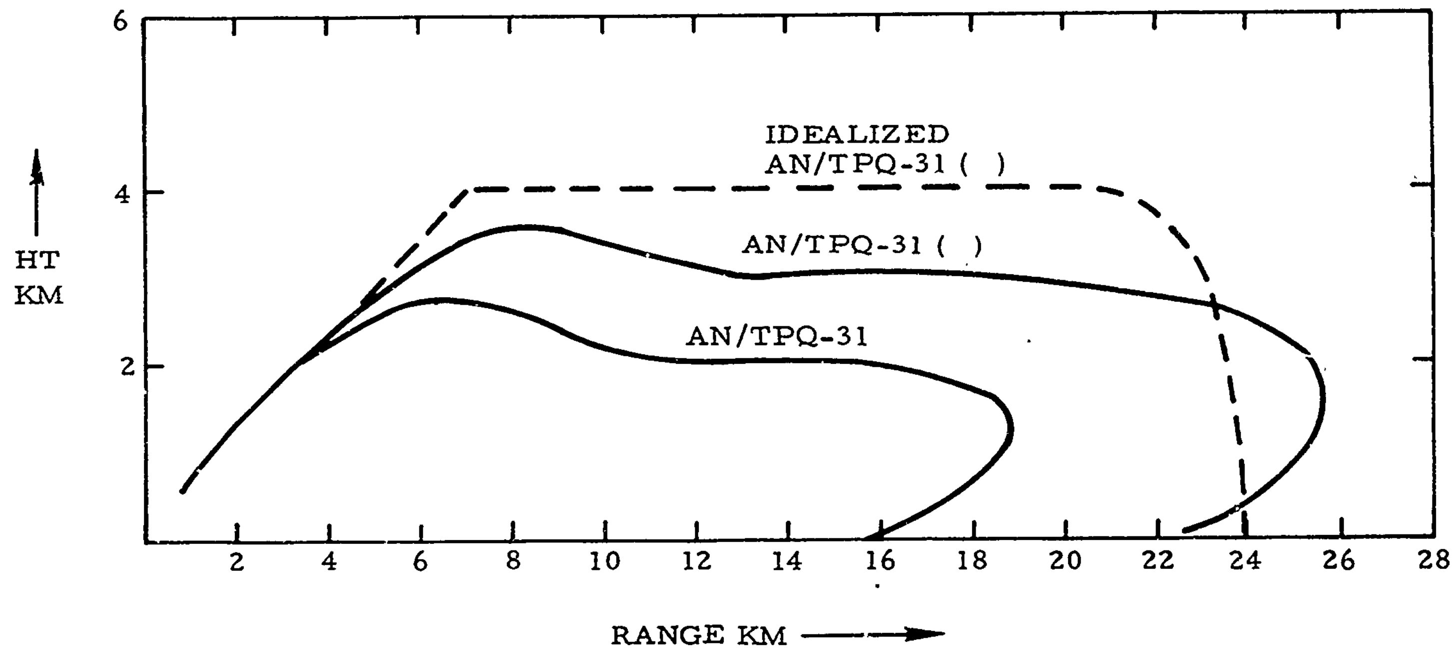


Figure 1. Radar Coverage for σ_T = 0.005 sq meter (No STC)

Annex D - (Wang 700A Calculator Program) to Report of AN/TPQ-31 Performance during Evaluation as a Hostile Weapon Locator

WANG 700A CALCULATOR PROGRAM

STORAGE REGISTERS USED

03	Height Difference (WEAPON - RADAR) in meters
04	Actual Weapon Azimuth in mils
05	Actual Weapon Range converted to meters
06	Mask angle in degrees
07	1st Det. Az converted to degrees
08	1st Det. Rg converted to meters
09	Last Det. Az converted to degrees
10	Last Det. Rg converted to meters
11	Number of hits minus one
*12	Number of rounds calculated in sequence
*13	Σ calculated Az in mils, Avg Az in mils
*14	Σ calculated Rg in meters, Avg Rg in meters
15	$X_2 - X_1$, Avg Az error in mils
16	$Y_2 - Y_1$, Avg Rg error in meters
17	Cartesian coord. $X_L(X_2, X_1, X_0, X_L)$
18	Cartesian coord. $Y_L(Y_2, Y_1, Y_0, Y_L)$
19	T^2
20	Calculated Az in mils = A_F
21	Mils to Degrees conversion
22	Kilometers to meters conversion

*Accumulating Registers.

23 Calculated Rg in meters = R_F

*24 Σ/Az error/, Average/Az error/

*25 Σ/Rg error/, Average/Rg error/

26 Working Register

*27 Σ RMS Az error, Average RMS Az error

*28 Σ RMS Rg error, Average RMS Rg error

*Accumulating Registers.

NOTE: Registers 00, 01, 02, 120 & 121 are used with the trig package.

FUNCTION KEYS USED

01 00 Clear storage register and store radar/weapon height in meters

01 01 Store actual azimuth and range of weapon in mils and KM

01 02 Store mask angle in degrees

01 03 Store 1st detection azimuth in mils and range in kilometers

01 04 Store last detection azimuth in mils and range in kilometers

01 05 Store number of scans

01 06 Calculate correction factor T^2 (display shows T^2 in Y and impact from C in the X register)

01 07 Calculate origin and errors

Display shows Az in mils/Rg in meters

Press GO and display shows:

Cartesian coordinates Y/X in meters

Press GO and display shows:

Error from actual Az in mils/Rg in meters

Press GO and display shows:

Miss distance in meters

01 08	Calculate averages - display shows average the same as 01 07
01 09	Calculate absolute averages - display shows absolute error Az in mils/Rg in meters
01 10	Store each individual Az and Rg error and compute difference from average
01 11	Calculate RMS average - display shows Az RMS error in mils/Rg RMS error in meters
	Press GO and display shows miss distance in meters

PROGRAM MARKS USED

0002	Sin X
0003	Cos X
0004	Tan X
0007	$Tan^{-1}X$
0100 0111	As described for function keys
0308	Quadrature II correction
0309	Quadrature II and III correction
0310	1st half of miss distance problem
0311	2nd half of miss distance problem
0312	Compute Az & Rg error
0313	Compute Mask correction
0314	Quadrature II and IV correction
0315	Clear registers 03 to 29
0801	Add 2 to value of T
0802	Subtract 2 from value of T

1513
1514 Used in trig program
1515

TOTAL NUMBER OF STEPS

699

VERIFICATION NUMBER

7097

COMPUTATIONS

R_1 = First range in meters

A_1 = First azimuth in degrees

R_2 = 2nd range in meters

A_2 = 2nd azimuth in degrees

N = Number of points from 1st to last

ϕ_m = Mask angle in degrees

H_R = Radar height in meters

H_W = Weapon height in meters

H_D = Difference height in meters (H_W - H_R)

Polar to Cartesian Coordinates

$X_1 = R_1 \text{ Sin } A_1$

$Y_1 = R_1 \cos A_1$

$X_2 = R_2 \text{ Sin } A_2$

$Y_2 = R_2 \cos A_2$

Origin if mask = 0°

$$X_0 = X_1 - 1/2\left(\frac{X_2 - X_1}{N - 1}\right), \quad Y_0 = Y_1 - 1/2\left(\frac{Y_2 - Y_1}{N - 1}\right)$$

Partial Time Correction (C)

$$C = \frac{A_2 - A_1}{180} \quad \text{if } C \begin{cases} < -1, & T = 2\,(N-1) + C + 2 \\ -1 \le C < 1, & T = 2\,(N-1) + C \\ \ge +1, & T = 2\,(N-1) + C - 2 \end{cases}$$

Mask Correction

$$B = 0.21\,(R_1 \tan \phi_m - H_D)/T^2$$

$$S_X = (X_2 - X_1)B, \quad S_Y = (Y_2 - Y_1)B$$

Computed Origin

$$X_L = X_0 - S_X \qquad Y_L = Y_0 - S_Y$$

$$A_F = \tan^{-1}\frac{X_L}{Y_L} \quad R_F = \frac{X_L}{\sin A_F}$$

AVERAGES

Accumulator adds Az in mils and range in meters.

Cartesian coordinates are computed from average polar coordinates.

Error subtracts actual from average polar coordinates.

Miss distance is computed from average error and average range.

Absolute error is accumulated from each individual error.

RMS error subtracts the average error from each individual error, squares it, accumulates sum of individual squares, takes average and the square root.

RMS miss distance is computed from RMS Az and Rg error and the average calculated range.

DATA SHEET

A sample data sheet is attached.

PROGRAM STEPS

Data sheets with the individual program steps are attached.

OPERATING PROCEDURE

1. Load and verify program.
2. Place toggle switch 10 in On position.
3. Key Radar Height in meters and raise to Y.
4. Key Weapon Height in meters.
5. Press function key 00 to enter height difference and clear all other storage registers.
6. Key actual weapon azimuth in mils and raise to Y.
7. Key actual weapon range in kilometers.
8. Press function key 01 to enter position.
9. Key mask angle in degrees.
10. Press function key 02 to enter data.
11. Key 1st detection Az & Rg as in steps 6 & 7.
12. Press function key 03.
13. Key last detection Az & Rg as in steps 6 & 7.
14. Press function key 04.
15. Key number of hits.
16. Press function key 05.
17. Press function key 06 to calculate factor T^2.

    (NOTE: Display shows T^2 in Y and in X either 0, +2, or -2 depending on the value of C.)
18. Press function key 07 to calculate origin.
19. Record azimuth in mils from Y and range in meters from X.
20. Press Go and record cartesian coordinates in meters.
21. Press Go and record azimuth error in mils from Y and range error in meters from X.

22. Press Go and record miss distance in meters from Y.

23. For each round in the sequence repeat steps 11 to 22.

24. When the last round is complete press function key 08.

25. Record average values for each column as in steps 19 to 22.

26. Press function key 09 and record the absolute error for azimuth and range.

27. Key the azimuth error from the 1st round and raise to Y.

28. Key the range error from the 1st round.

29. Press function key 10 to store RMS in an accumulator.

    (NOTE: The display shows the square of the difference between the error and the average error.)

30. Repeat steps 27 to 29 for each round in the sequence.

31. When the last round is complete, press function key 11 to compute the RMS values.

32. Record the RMS azimuth error in mils and the RMS range error in meters.

33. Press Go and record the RMS miss distance in meters.

34. When starting the next sequence be sure to start again at step 3 in order to clear the accumulators.

NOTE: When storing information from individual rounds in steps 11 to 16, it is not necessary to re-enter information if it was the same as the previous round. All other steps should be performed.

AN/TPQ-31 EVALUATION TEST # ________ SEQUENCE # ________

Radar Ht. ________ M, Actual Weapon Location: Ht. ________ M, Az ________ mils, Rg ________ Km, Mask Angle ______ °

Radar Location ____________

1st Detection		Last Detection		No. of Hits	Calculated Origin				Error from Actual		
Az. Mils	Rg Km	Az. Mils	Rg Km		Az. Mils	Rg Meters	Y Meters	X Meters	Az Mils	Rg Meters	Miss Dist. Meters
		Average									
							Avg. Absolute Error				
							RMS Error				

Step		Key	Code	Comment
	0	MARK	0408	Sin(x) Start
	1	0002	0002	
	2	↓	0604	
	3	9	0709	Requires Cos(x)
	4	0	0700	
	5		0601	
	6	↓	0605	
	7	MARK	0408	Cos(x) - Start
	8	0003	0003	
	9	↓	0604	
01	0	3	0703	
	1	6	0706	
	2	0	0700	
	3	÷	0603	
	4	↓	0605	
	5	INT X	0608	
	6	−	0601	
	7	4	0704	
	8	X	0602	
	9	↓	0605	
02	0	INT X	0608	
	1	−	0601	
	2	WRITE A	0412	
	3	$\sqrt{x}$	0612	COSINE TEST
	4	π	0609	
	5	X	0602	
	6	2	0702	
	7	÷	0603	
	8	↓	0605	
	9	x^2	0713	
03	0	ST DIR	0404	
	1	REG 120	1200	x^2
	2	1	0701	
	3	6	0706	
	4	↓	0604	
	5	1	0701	
	6	ST DIR	0401	
	7	REG 00	0000	Ans
	8	MARK	0408	
	9	1514	1514	

Step		Key	Code	Comment
04	0	RE DIR	0405	
	1	REG 120	1200	
	2	X DIR	0402	
	3	REG 00	0000	
	4	↓	0605	
	5	÷ DIR	0403	
	6	REG 00	0000	
	7	1	0701	
	8	-	0601	
	9	↓	0605	
05	0	CH SIGN	0711	
	1	÷ DIR	0403	
	2	REG 00	0000	
	3	1	0701	
	4		0601	
	5	+ DIR	0400	
	6	REG 00	0000	
	7	WRITE A	0412	
	8	WRITE	0411	Y = 0
	9	SEARCH	0407	
06	0	1514	1514	
	1	KEY	0415	
	2	REG 00	0000	
	3		0712	
	4	5	0705	
	5	SET EXP	0710	
	6	CH SIGN	0711	
	7	1	0701	
	8	1	0701	
	9		0601	
07	0		0601	
	1	↓	0605	
	2	WRITE A	0412	
	3	END PROG	0512	Set Sign
	4	SEARCH	0407	
	5	1515	1515	Sin(x),Cos(x)-End
	6	MARK	0408	$Tan^{-1}(x)$-Start
	7	0007	0007	
	8	WRITE A	0412	
	9	CLEAR X	0715	Arc Tan Test 90°

Step		Key	Code	Comment
08	0	↑	0601	
	1		0712	
	2	5	0705	
	3	SKIP IF Y>X	0507	
	4	WRITE A	0412	
	5	X^2	0713	Arc Tan Test 45°
	6	1	0701	
	7	ı	0600	
	8	ST Y	0414	
	9	REG 00	0000	
09	0	2	0702	
	1	−	0601	
	2	RE DIR	0405	
	3	REG 00	0000	
	4	÷	0603	
	5	↑	0605	
	6	ST Y	0414	input/ans.
	7	REG 01	0001	
	8	×	0602	
	9	ST Y	0414	angle x^2
10	0	REG 00	0000	
	1	1	0701	
	2	ST DIR	0404	partial prod.
	3	REG 120	1200	
	4	1	0701	
	5	5	0705	
	6	↑	0604	
	7	8	0708	
	8	ST DIR	0404	inner prod.
	9	REG 02	0002	
11	0	MARK	0408	
	1	1513	1513	
	2	RE DIR	0405	
	3	REG 00	0000	
	4	X DIR	0402	
	5	REG 120	1200	
	6	RE DIR	0405	
	7	REG 02	0002	
	8	X DIR	0402	
	9	REG 02	0002	

Step		Key	Code	Comment
12	0	EX DIR	0406	
	1	REG 02	0002	
	2	X DIR	0402	
	3	REG 120	1200	
	4	↑	0605	
	5	+ DIR	0400	
	6	REG 120	1200	
	7	2	0702	
	8		0601	
	9	1	0701	
13	0	DIR	0401	
	1	REG 02	0002	
	2	EX DIR	0406	
	3	REG 120	1200	
	4	÷ DIR	0403	
	5	REG 120	1200	
	6	RE DIR	0405	
	7	REG 02	0002	
	8	WRITE A	0412	
	9	$LOG_e X$	0611	Skip X = 0
14	0	SEARCH	0407	
	1	1513	1513	
	2	RE Y	0415	
	3	REG 01	0001	
	4	RE DIR	0405	
	5	REG 120	1200	
	6	×	0602	
	7	WRITE A	0412	
	8	GO	0514	$180/\pi$
	9	×	0602	
15	0	4	0704	
	1	5	0705	
	2	WRITE A	0412	
	3	10^x	0613	Arc Tan Set
	4	↑	0605	
	5	WRITE A	0412	
	6	END PROG	0512	Set Sign
	7	SEARCH	0407	
	8	1515	1515	$Tan^{-1}(x)$-End
	9	MARK	0408	Tan(x) –Start

Step	Key	Code	Comment
160	0004		
1	ST DIR		
2	01		
3	SR0002		
4	⇄ DIR		
5	01		
6	SR 0003		
7	÷ DIR		
8	01		
9	REC DIR		
170	01		
1	RETURN		
2	MARK		
3	1515		
4	REC Y		
5	121		
6	RETURN		END OF TIRG PKG.
7	MARK		CLEAR AND
8	0100		RADAR/WEAP HT.
9	↑↓		
180	—		
1	ST Y		
2	03		
3	0		
4	4		
5	↑		
6	SR 0315		
7	0		
8	↑		
9	STOP		
190	MARK		WEAPON ACTUAL
1	0101		AZ/RG
2	ST DIR		
3	05		
4	.		
5	0		
6	5		
7	6		
8	2		
9	5		

Step	Key	Code	Comment
200	GO		
1	ST Y		
2	04		
3	ST DIR		
4	21		
5	1		
6	0		
7	0		
8	0		
9	X DIR		
210	05		
1	ST DIR		
2	22		
3	0		
4	↑		
5	STOP		
6	MARK		
7	0102		MASK X
8	ST DIR		
9	06		
220	0		
1	STOP		
2	MARK		1ST DET.
3	0103		AZ/RG.
4	ST DIR		
5	08		
6	REC DIR		
7	21		
8	X		
9	ST Y		
230	07		
1	REC DIR		
2	22		
3	X DIR		
4	08		
5	0		
6	↑		
7	STOP		
8	MARK		LAST DET.
9	0104		AZ/RG

Step	Key	Code	Comment
240	ST DIR		
1	10		
2	REC DIR		
3	21		
4	X		
5	ST Y		
6	09		
7	REC DIR		
8	22		
9	X DIR		
250	10		
1	0		
2	↑		
3	STOP		
4	MARK		
5	0105		No. OF HITS
6	↑		
7	1		
8	—		
9	ST Y		
260	11		
1	0		
2	↑		
3	STOP		
4	MARK		COMPUTE T^2
5	0106		
6	REC Y		
7	11		
8	2		
9	X		
270	ST Y		
1	19		
2	REC. Y		
3	09		
4	REC DIR		
5	07		
6	—		
7	1		
8	8		
9	0		

Step	Key	Code	Comment
280	÷		
1	↓		
2	+ DIR		
3	19		
4	1		
5	CHG SIGN		
6	SKIP IF Y≥X		
7	SEARCH		
8	0801		
9	CHG SIGN		
290	SKIP IF Y<X		
1	SEARCH		
2	0802		
3	REC DIR		
4	19		
5	X^2		
6	ST DIR		
7	19		
8	↑		
9	0		
300	STOP		
1	MARK		
2	0801		ADD 2 TO T
3	REC Y		
4	19		
5	2		
6	+		
7	↑↓		
8	X^2		
9	ST DIR		
310	19		
1	↑↓		
2	STOP		
3	MARK		
4	0802		SUB 2 FROM T
5	REC Y		
6	19		
7	2		
8	CHG SIGN		
9	+		

Step	Key	Code	Comment
320	↑↓		
1	x^2		
2	ST DIR		
3	19		
4	↑↓		
5	STOP		
6	MARK		
7	0107		COMPUTE ORIGIN
8	REC DIR		
9	09		A_2
330	SR 0002		
1	↑		
2	REC DIR		
3	10		R_2
4	X		
5	ST Y		
6	17		X_2
7	REC DIR		
8	07		A_1
9	SR 0002		
340	↑		
1	REC DIR		
2	08		R_1
3	X		
4	↓		
5	⇌ DIR		
6	17		X_1
7	↑↓		
8	−		
9	ST Y		
350	15		$X_2 - X_1$
1	REC DIR		
2	11		$(N-1)$
3	÷		
4	2		
5	÷		
6	↓		
7	− DIR		
8	17		X_0
9	REC DIR		

Step	Key	Code	Comment
360	09		A_2
1	SR 0003		
2	↑		
3	REC DIR		
4	10		R_2
5	X		
6	ST Y		
7	18		y_2
8	REC DIR		
9	07		A_1
370	SR 0003		
1	↑		
2	REC DIR		
3	08		R_1
4	X		
5	↓		
6	⇌ DIR		
7	18		y_1
8	↑↓		
9	−		
380	ST Y		
1	16		$y_2 - y_1$
2	REC DIR		
3	11		$(N-1)$
4	÷		
5	2		
6	÷		
7	↓		
8	− DIR		
9	18		Y_0
390	REC DIR		
1	06		mag ∠ X
2	SR 0004		tan X
3	↑		
4	0		
5	SKIP IF Y=X	0509	
6	GO		
7	SR 0313		CORRECTION FACTOR
8	REC Y		
9	18		Y_L

Step	Key	Code	Comment
0			
1			
2	ADDITIONAL		STEPS
3	REQUIRED TO		CORRECT
4	FOR TAN $^{-1}$		OF ANGLES
5	IN THE 2ND		& 3RD
6	QUADRANT		
7			
8			
9			
400	CLEAR X		
1	ST DIR		
2	20		
3	WRITE A		SKIP IF
4	GROUP II		Y is +
5	GO		
6	SR 0309		QUAD II & III
7	REC DIR		
8	17		X_L
9	↑↓		
410	÷		
1	↓		
2	SR 0007		Tan $^{-1}$
3	↑		
4	0		
5	SKIP IF Y≥X		
6	GO		
7	SR 0314		QUAD II & IV
8	↓		
9	+ DIR		
420	20		
1	REC DIR		
2	20		A_F^{0}
3			
4			
5			
6			
7			
8			
9			

Step	Key	Code	Comment
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			

Step	Key	Code	Comment
r			
1			
2			
3			
4			
5			
6			
7			
8			
9			
0			
1			
2			
423	SR 0002		sin ∡
4	REC Y		
5	17		X_L
6	÷		
7	S→Y		
8	23		R_F
9	REC DIR		
430	21		MILS → DEG
1	1/x		DEG → MILS
2	X DIR		
3	20		A_F (MILS)
4	1		
5	+ DIR		
6	12		COUNTER
7	↓		
8	+ DIR		
9	14		R_F ACCUM.
440	REC DIR		
1	20		A_F (MILS)
2	+ DIR		
3	13		A_F ACCUM
4	↑↓		
5	STOP		
6	REC Y		
7	18		Y_L
8	REC DIR		
9	17		X_L

Step	Key	Code	Comment
450	STOP		
1	REC Y		
2	20		A_F (MILS)
3	REC DIR		
4	23		R_F (METERS)
5	SR 0312		COMPUTE ERROR
6	STOP		
7	|x|		
8	+ DIR		
9	25		Σ |R_G ERROR|
460	↑↓		
1	|x|		
2	+ DIR		
3	24		Σ |A_Z ERROR|
4	↑↓		
5	SR 0310		COMPUTE MISS
6	SR 0004		tan ∡
7	REC Y		
8	23		R_F
9	SR 0311		COMPUTE MISS
470	0.		
1	STOP		
2	GO		
3	GO		
4	GO		
5	MARK		COMPUTE
6	0108		AVERAGES
7	REC DIR		
8	12		No.
9	÷ DIR		
480	14		AVG R_G
1	÷ DIR		
2	13		AVG A_Z
3	REC Y		
4	13		
5	REC DIR		
6	14		
7	STOP		
8	REC DIR		
9	21		MILS → DEG.

Step	Key	Code	Comment
490	X		
1	↓		
2	ST DIR		
3	26		
4	SR 0002		sin ∡
5	↑		
6	REC DIR		
7	14		AVG RG
8	X		
9	↓		
500	⇄ DIR		
1	26		
2	SR 0004		tan ∡
3	÷		
4	REC DIR		
5	26		
6	STOP		AVG CARTESIAN COORD.
7	REC Y		
8	13		AVG AZ
9	REC DIR		
510	14		AVG RG
1	SR 0312		COMPUTE ERROR
2	ST Y		
3	15		AVG AZ ERROR
4	ST DIR		
5	16		AVG RG. ERROR
6	STOP		
7	SR 0310		COMPUTE MISS
8	SR 0004		tan ∡
9	REC Y		
520	14		AVG RG
1	SR 0311		COMPUTE MISS
2	0.		
3	STOP		
4	MARK		AVERAGE
5	0109		ABSOLUTE ERROR
6	REC DIR		
7	12		NO.
8	÷ DIR		
9	24		AVG |AZ error|

Step	Key	Code	Comment
530	÷ DIR		
1	25		AVG |RG error|
2	REC Y		
3	24		
4	REC DIR		
5	25		
6	STOP		
7	MARK		ENTER
8	0110		ERROR DATA
9	ST DIR		
540	26		
1	REC DIR		
2	15		AVG AZ ERROR
3	−		
4	↓		
5	X^2		
6	+ DIR		
7	27		Σ RMS AZ error
8	⇄ DIR		
9	26		
550	↑		
1	REC DIR		
2	16		AVG RG ERROR
3	−		
4	↓		
5	X^2		
6	+ DIR		
7	28		Σ RMS RG ERROR
8	REC Y		
9	26		
560	STOP		
1	MARK		COMPUTE
2	0111		RMS ERROR
3	REC DIR		
4	12		NO.
5	÷ DIR		
6	27		AVG RMS AZ error
7	÷ DIR		
8	28		AVG RMS RG error
9	REC DIR		

Step	Key	Code	Comment
570	27		
1	√x		
2	↑		
3	REC DIR		
4	28		
5	√x		
6	STOP		
7	SR 0310		COMPUTE MISS
8	SR 0004		Tan ∡
9	REC Y		
580	14		AVG RG
1	SR 0311		COMPUTE MISS
2	0		
3	STOP		FUNCTIONS COMPLETE
4	MARK		COMPUTE 1ST HALF
5	0310		MISS DISTANCE
6	X^2		
7	ST DIR		
8	26		
9	↓		
590	REC Y		
1	21		MILS → DEG
2	X		
3	↓		
4	RETURN		
5	MARK		COMPUTE 2ND HALF
6	0311		MISS DISTANCE
7	X		
8	↓		
9	X^2		
600	+ DIR		
1	26		
2	REC DIR		
3	26		
4	√x		
5	↑		
6	RETURN		
7	MARK		COMPUTE
8	0312		ERROR
9	ST DIR		

Step	Key	Code	Comment
610	26		
1	REC DIR		
2	04		ACTUAL AZ
3	—		
4	↓		
5	⇄ DIR		
6	26		
7	↑		
8	REC DIR		
9	05		ACTUAL RG
620	—		
1	REC DIR		
2	26		
3	↑↓		
4	RETURN		
5	MARK		MASK ∡
6	0313		CORRECTION
7	REC DIR		
8	08		R_1
9	X		
630	REC DIR		
1	03		H_D
2	—		
3	REC DIR		
4	19		T^2
5	÷		
6	•		
7	~~0~~ 2		
8	~~0~~ 1		
9	30		
640	60		
1	80		
2	40		
3	X		
4	↓		B
5	REC Y		
6	15		$(Y_2 - Y_1)$
7	X		
8	↑↓		
9	— DIR		

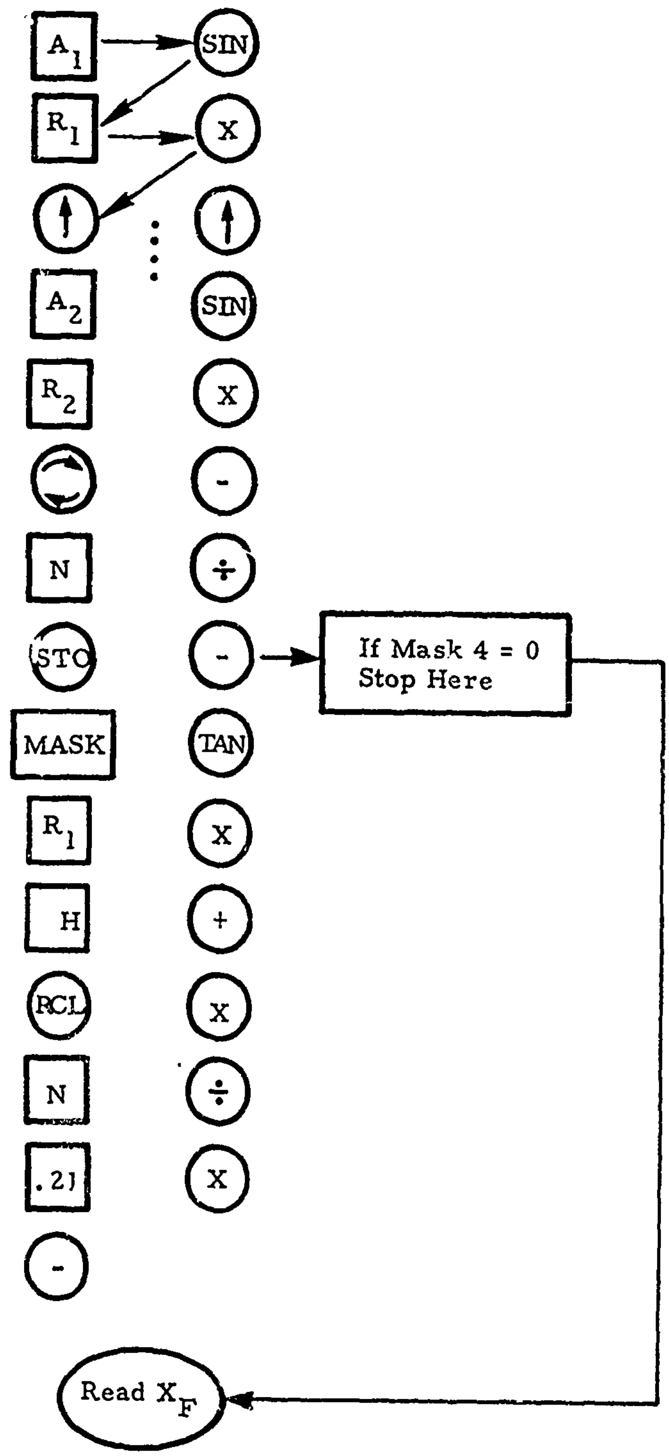
Step	Key	Code	Comment
650	17		X_L
1	REC DIR		$(y_2 - y_1)$
2	16		
3	X		
4	↓		
5	− DIR		
6	18		Y_L
7	RETURN		
8	MARK		QUADRANT
9	0314		II & IV.
660	3		
1	6		
2	0		
3	+		
4	RETURN		
5	MARK		CLEAR
6	0315		REGISTERS
7	0		
8	ST IND		
9	1		
670	+		
1	3		
2	0		
3	SKIP IF Y=X		
4	SEARCH		
5	0315		
6	RETURN		
7	MARK		QUADRANT
8	0309		II & III
9	1		
680	8		
1	0		
2	+ DIR		
3	20		
4	REC DIR		
5	17		X_L
6	WRITE A		SKIP IF
7	SET EXP		X 13 —
8	GO		
9	SR0308		QUAD II

Step	Key	Code	Comment
690	RETURN		
1	MARK		QUADRANT
2	0308		II
3	3		
4	6		
5	0		
6	− DIR		
7	20		
8	RETURN		
9	END PROG		
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			

Appendix 1 - (HP 35 Program) to Annex D of Report of AN/TPQ-31

Performance during Evaluation as a Hostile Weapon Locator

A miniature Hewlett Packard calculator, HP-35, was also used to compute firing points and is believed to be a valuable time saving asset for such application. The program (based on certain approximations) to compute firing points on the HP-35 (N' is equal to 2(N - 1)) is presented on the following page. The boxes represent data entry and the circles represent function buttons. The "Y" coordinate of the firing point, Y_F, is obtained using the same program, but by pressing COS whenever SIN is called for. The execution time for computing both X_F and Y_F was found to be 1-3/4 minutes total for someone modestly familiar with the calculator.



BACKTRACK COMPUTATION ON HP-35 HAND CALCULATOR

Annex E - (Dahlgren Test Results) to Report of AN/TPQ-31 Performance During Evaluation as a Hostile Weapon Locator

1. The raw data of the tests at Dahlgren is contained in Appendix 1 to this Annex. This data reflects target information collected on the following dates: December 1, 4, 6 and 7, 1972.

a. Twenty-six rounds artillery were tracked on 1 December. The data is far from complete, but is included for record purposes. No back data could be obtained from the main range personnel as to weapon type, Q. E., etc.

b. On 4 December, 18 rounds of 81 mm mortar were tracked and plotted. Although these rounds were not part of the scheduled program, weapon type and Q. E. information was made available. The predicted firing point location was estimated manually by the operator. The basic method of manual processing target information by the operator includes the plotting of mortar shells, artillery shells or missiles with a grease pencil on the face of the PPI crt. Starting at the point of origin, where the target was first detected, the operator follows the line of flight of the target by drawing a line through each of its target returns. Successive plotting of targets starting at their first point of detection helps the operator determine the point of origin of the hostile weapon emplacement. The range (distance) of the point of origin is determined by pointing the azimuth cursor to the first point of target detection and rotating the TARGET RANGE DESIGNATION control so the azimuth cursor touches the leading edge of the first target return. The azimuth of the target can then be determined by the azimuth scale on the outer edge of the PPI crt, and the range read off the digital range counter.

c. The first half of scheduled mortar rounds to be observed from site 7 were fired from the main range firing point on 6 December and the second half on

7 December. The raw data for these dates shows the predicted origin of the firing point estimated manually by the operator. Tables F-1 through F-6 show this data when processed by a hand calculator (Wang).

2. For launch point calculation with the calculator, 6830 meters and 5655 mils were used as the best known range and bearing of the firing point from the radar. The following equations were evaluated on the hand calculator for each radar reading to yield a table of range launch point (R_o), and azimuth launch points (Az_o), *

$$R_o = \frac{R_1 - R_2}{2(N - 1)} 4 R_1$$

$$Az_o = \frac{Az_1 - Az_2}{2(N - 1)}$$

where for a particular round,

R_1 is the first detection range

Az_1 is the first detection Az

R_2 is the last detection range

Az_2 is the last detection Az

N is the number of scans between and including the first and last detections

These values are listed in the data column of the Tables E-1 through E-8. On line 2, Appendix E-1-1, and lines 2, 3, 4, 6 and 12, Appendix E-1-2, Annex E, are first look range values which cannot be correct because they are less than the last

*These results are approximate as the equations yield acceptable results only when the difference between the first and last azimuth is small, as was true in this case.

look value. This is assumed to be an operator error and 5 is assumed to be the correct first digit. Rounds 6, Tables E-1 and E-2 and 9, Tables E-7 and E-8, were not included in the computer runs because of no track.

GROUPING

There are 4 groups of firings:

Group 1 Ch 8 - 45°	Tables E-1 and E-2
Group 2 Ch 6 - 65°	Tables E-3 and E-4
Group 3 Ch 2 - 65°	Tables E-5 and E-6
Group 4 Ch 8 - 25°	Tables E-7 and E-8

All but group 4 were below the blind notch of the radar at PRR - 1600 Hz. Group 4 have a muzzle velocity of 248 m/s which becomes 225 m/s in the ground plane for QE = 25°. Since the system clutter notch extends from 154 to 198 m/s an occasional sighting may be expected just before the shell drops into the blind zone if the antenna rotation timing is just right. However, since the data of group 4 were beyond the design parameters of the AN/TPQ-31 they will be presented separately and not combined with the remaining data. Group 1 firings have an initial radial component of approximately 175 m/s which is still wi: in the 3 dB points in the notch, but are reasonably well detected because of the signal strength overcoming the value of the notch skirt at that point.

3. In Tables E-1 through E-8 a printout of the reduced data for groups 1, 2 and 3 are presented.

An overall bias for all the values (59 rounds) was computed to be:

Range bias	58.4 m
Az bias	-2.42 mils

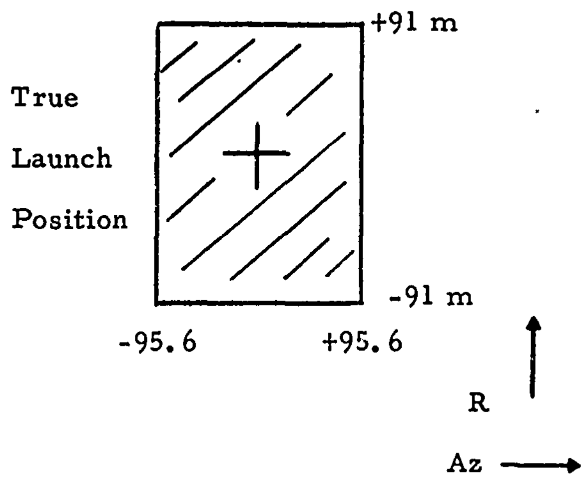
$$\text{BIAS} = \frac{1}{N}\sum^{N} X_i - \text{True Value}$$

The average value for predicted launch range and azimuth is printed out for each group as well as the offset that value represents.

The error for each point is tabulated, as well as the error per point corrected by the 59 round bias.

The group variance for R_o and Az_o is printed below each group as well as the average value of the absolute error.

The prediction Footprint for the 59 Values of Groups 1, 2 and 3, with bias removed, within which 50% of all predictions fall, is presented as follows:



Area = 34,798 sq meters

Radius of circle of equivalent area:

$$R_{CEP}\sqrt{\frac{34,798}{\pi}} = 105.2 \text{ meters}$$

4. The values in Tables E-7 and E-8 are presented separately with no further analysis because the projectile entered the radar blind zone shortly after firing. Errors of 592 m range bias and 37.6 mils Az bias resulted.

Table E-1

RANGE

RNH

6 Dec. 72
Charge 8
45°

Best known RO = 6830 meters, AZO = 5655 mils
59 round bias = 58.4 meters range and -2.42 mils AZ
Avg value = 6904.8 meters
Offset of avg of values = 74.8 meters

Rd.	Data R_O	Error	Error Less Bias	
1	6720	-110	-168.373	
2	7120	290	231.627	
3	7410	580	521.627	
4	6900	70	11.6271	
5	6910	80	21.6271	
6*				
7	6900	70	11.6271	
8	6600	-230	-288.373	
9	6900	70	11.6271	
10	7080	250	191.627	
11	7100	270	211.627	
12	6910	80	21.6271	
13	7010	180	121.627	
14	7010	180	121.627	
15	6850	20	-38.3729	
16	6790	-40	-98.3729	
17	6800	-30	-88.3729	
18	6590	-240	-298.373	
19	6590	-240	-298.373	
20	7010	180	121.627	
21	6870	40	-18.3729	
22	6900	70	11.6271	
23	6990	160	101.627	
24	6670	-160	-218.373	
25	7010	180	121.627	Charge 6
26	6980	150	91.6271	65°

Variance = 182.912 meters rms
Avg ABS error = 158.8 meters

*Round 6 not included because of no track.

Table E-2

AZIMUTH

RNH

6 Dec. 72
Charge 8
45°

Best known RO = 6830 meters, AZO = 5655 mils
59 round bias = 58.4 meters range and -2.42 mils AZ
Avg value = 5656.6 mils
Offset of avg of values = 1.6 mils

Rd.	Data Az.	Error	Error Less Bias	
1	5638	-17	-14.5763	
2	5660	5	7.42373	
3	5672	17	19.4237	
4	5682	27	29.4237	
5	5661	6	8.42373	
6*				
7	5640	-15	-12.5763	
8	5650	-5	-2.57627	
9	5670	15	17.4237	
10	5643	-12	-9.57627	
11	5639	-16	-13.5763	
12	5638	-17	-14.5763	
13	5648	-7	-4.57627	
14	5647	-8	-5.57627	
15	5689	34	36.4237	
16	5649	-6	-3.57627	
17	5658	3	5.42373	
18	5654	-1	1.42373	
19	5658	3	5.42373	
20	5668	13	15.4237	
21	5694	39	41.4237	
22	5644	-11	-8.57627	
23	5639	-16	-13.5763	
24	5660	5	7.42373	
25	5651	-4	-1.57627	Charge 6
26	5663	8	10.4237	65°

Variance = 15.4454 mils rms
Avg ABS error = 12.4 mils

*Round 6 not included because of no track.

Table E-3

RANGE

7 Dec. 72
Charge 6
65°

Best known RO = 6830 meters, AZO = 5655 mils
59 round bias = 58.4 meters range and -2.42 mils AZ
Avg value = 6864.58 meters
Offset of avg of values = 34.5833 meters

Rd.	Data R_o	Error	Error Less Bias
1	7050	220	161.627
2	6640	-190	-248.373
3	7180	350	291.627
4	6680	-150	-208.373
5	6870	40	-18.3729
6	7070	240	181.627
7	7070	240	181.627
8	6790	-40	-98.3729
9	6570	-260	-318.373
10	7070	240	181.627
11	6680	-150	-208.373
12	6980	150	91.6271
13	6460	-370	-428.373
14	6870	40	-18.3729
15	6750	-80	-138.373
16	6970	140	81.6271
17	6480	-350	-408.373
18	6960	130	71.6271
19	6970	140	81.6271
20	6970	140	81.6271
21	6970	140	81.6271
22	6870	40	-18.3729
23	6970	140	81.6271
24	6860	30	-28.3729

Variance = 190.853 meters rms
Avg ABS error = 167.083 meters

Table E-4

AZIMUTH

7 Dec. 72
Charge 6
65°

Best known RO = 6830 meters, AZO = 5655 mils
59 round bias = 58.4 meters range and -2.42 mils AZ
Avg value = 5654.08 mils
Offset of avg of values = 0.916667 mils

Rd.	Data Az_o	Error	Error Less Bias
1	5614	-41	-38.5763
2	5643	-12	-9.57627
3	5613	-42	-39.5763
4	5686	31	33.4237
5	5642	-13	-10.5763
6	5647	-8	-5.57627
7	5635	-20	-17.5763
8	5676	21	23.4237
9	5676	21	23.4237
10	5646	-9	-6.57627
11	5667	12	14.4237
12	5625	-30	-27.5763
13	5677	22	24.4237
14	5667	12	14.4237
15	5646	-9	-6.57627
16	5667	12	14.4237
17	5665	10	12.4237
18	5656	1	3.42373
19	5667	12	14.4237
20	5646	-9	-6.57627
21	5646	-9	-6.57627
22	5667	12	14.4237
23	5656	1	3.42373
24	5668	13	15.4237

Variance = 19.0873 mils rms
Avg ABS error = 15.9167 mils

Table E-5

RANGE

Best known RO = 6830 meters, AZO = 5655 mils — 7 Dec. 72
59 round Bias = 58.4 meters range and -2.42 mils AZ — Charge 2
Avg value = 6904.4 meters — 65°
Offset of avg of values = 74.4 meters

Rd.	Data R_o	Error	Error Less Bias
1	6943	113	54.6271
2	6938	108	49.6271
3	6842	12	-46.3729
4	6950	120	61.6271
5	6943	113	54.6271
6	6955	125	66.6271
7	6950	120	61.6271
8	6844	14	-44.3729
9	6841	11	-47.3729
10	6838	8	-50.3729

Variance = 51.7672 meters rms
Avg ABS error = 74.4 meters

Table E-6

AZIMUTH

Best known RO = 6830 meters, AZO = 5655 mils — 7 Dec. 72
59 round bias = 58.4 meters range and -2.42 mils AZ — Charge 2
Avg value = 5638.9 mils — 65°
Offset of avg of values = -16.1 mils

Rd.	Data AZ_o	Error	Error Less Bias
1	5635	-20	-17.5763
2	5635	-20	-17.5763
3	5645	-10	-7.57627
4	5647	-8	-5.57627
5	5636	-19	-16.5763
6	5637	-18	-15.5763
7	5645	-10	-7.57627
8	5636	-19	-16.5763
9	5637	-18	-15.5763
10	5636	-19	-16.5763

Variance = 4.50444 mils rms
Avg ABS error = 16.1 mils

Table E-7

RANGE

7 Dec. 72
Charge 8
25°

Avg value = 6237.62 meters
Bias of avg of values = -598.379 meters

Rd.	Data R_o	Error	Error Less Bias
1	5960	-870	-277.621
2	5608	-1222	-629.621
3	5410	-1420	-827.621
4	5425	-1405	-812.621
5	5630	-1200	-607.621
6	5250	-1580	-987.621
7	7050	220	812.379
8	6115	-715	-122.621
9*			
10	5881	-949	-356.621
11	5878	-952	-359.621
12	5894	-936	-343.621
13	6128	-702	-109.621
14	5410	-1420	-827.621
15	5825	-1005	-412.621
16	6703	-127	465.379
17	6496	-334	258.379
18	7035	205	797.379
19	6303	-527	65.3793
20	6507	-323	269.379
21	6910	80	672.379
22	6511	-319	273.379
23	7010	180	772.379
24	6104	-726	-133.621
25	6717	-113	479.379
26	6715	-115	477.379
27	6503	-327	265.379
28	6500	-330	262.379
29	6906	76	668.379
30	6507	-323	269.379

Variance = 536.068 meters rms
Avg ABS error = 644,868 meters

*Round 9 not included because of no track.

Table E-8

AZIMUTH

7 Dec. 72
Charge 8
QE 25°

RNH

Avg value = 5692.59 mils
Bias of avg of values = 37.5862 mils

Rd.	Data AZ_o	Error	Error Less Bias
1	5689	34	-3.58621
2	5719	64	26.4138
3	5707	52	14.4138
4	5742	87	49.4138
5	5720	65	27.4138
6	5723	68	30.4138
7	5608	-47	-84.5862
8	5714	59	21.4138
9*			
10	5711	56	18.4138
11	5683	28	-9.58621
12	5700	45	7.41379
13	5755	100	62.4138
14	5775	120	82.4138
15	5689	34	-3.58621
16	5651	-4	-41.5862
17	5655	0	-37.5862
18	5630	-25	-62.5862
19	5701	46	8.41379
20	5692	37	-0.586207
21	5704	49	11.4138
22	5670	15	-22.5862
23	5662	7	-30.5862
24	5690	35	-2.58621
25	5680	25	-12.5862
26	5680	25	-12.5862
27	5691	36	-1.58621
28	5692	37	-0.586207
29	5671	16	-21.5862
30	5681	26	-11.5862

Variance = 33.9721 mils rms
Avg ABS error = 42.8276 mils

*Round 9 not included because of no track.

Appendix 1 - (Recorded Test Data from Dahlgren Tests) to Annex E of Report of AN/TPQ-31 Performance Evaluation as a Hostile Weapon Locator

TEST FIRINC RESULTS

Radar AN/TPQ-31 Location Site 7 Date Dec 1, 1972

Round	Time	1st Det R	1st Det Az	Last Det R	Last Det Az	Predicted Origin R	Predicted Origin Az	Target Track 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1		5670	6.6	5720	5.9			X	X																	
2		5670	6.9																							
3		5860	4.6	1140	2.5	5425	6250	X	X	X	X															
4		5830	6.4	1340	2.9	5790	7200	X	X	X	X	X	X	X	X	X	X									
5		5820	5.1	1140	2.5			Missed																		
6		5710	6.6	1260	2.6	5990	7200	X	X	X	O	X	X	X	X	X	X									
7		5860	5.4	1250	2.6	5715	6050	X	X	O	X	X	X	X	X											
8		5840	5.4	1470	3.1	5785	5550	X	X	O	X	X	X	X	X	X										
9		5860	4.9	1550	3.1	5800	5700	X	O	X	X	O	X	X	X											
10		5870	4.8	1220	2.7	5795	5600	X	O	X	O	X	X	X												
11		5770	6.1	1170	2.5	5715	7200	X	X	X	X	X	X	X												
12		5740	6.1	1190	2.4	5685	7200	X	O	X	X	X	X	X	X											
13		5850	5.0	1220	2.7	5765	6050	X	X	X	O	X	X	X												
14		5850	5.0	1210	2.6	5765	6026	X	X	X	X	X	X													
15		5680	6.7	1300	2.7	5640	7580	X	X	O	X	O	O	X	X	X										
16		5740	6.2	1320	2.6	5695	7000	X	X	O	X	O	X	X	X	X										

TEST FIRING RESULTS

Radar AN/TPQ-31 Location Site 7 Date Dec. 1, 1972

Round	Time	1st Det R	1st Det Az	Last Det R	Last Det Az	Predicted Origin R	Predicted Origin Az	Target Track 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1415	5730	6.4	6380	6.4			X	X						Burst											
2	1420	5740	5.8	1500	3.5			X	X	X	X	X	X													
3	1423	5780	5.5	1615	4.3						Missed															
4	1423	5790	5.2	1510	3.8			X	X	O	X	X	O	X												
5	1424	5730	6.5	1550	3.9			X	X	X	X	X	X	O	X											
6	1425	5700	7.0	1640	8.6			X	X	X	X	X	X	X	O	X	X									
7	1426	5760	5.7	2000	10.2			X	X	X	X	O	X	O	X	X	X									
8	1427	5730	6.1	2060	7.8			X	X	X	O	X	X	X	X											
9	1428	5750	5.6	1960	8.4			X	X	X	O	X	X	X	X											
10	1429	5760	5.9	1950	8.2						Missed															
11	1430	5710	6.6	1960	8.0						Missed															
12	1431	5720	6.7	1910	7.8			X	X	X	X	O	X	O	X	X	X									
13	1432	5750	5.9	1970	8.4						Missed															
14	1433	5740	6.3	1950	7.5			X	X	X	X	X	X	O	X	X	X									
15	1434	5730	6.2	1910	7.6						Missed															
16	1435	5710	6.5	1810	5.7			X	X	X	X	X	X	X	X											
17	1436	5800	5.5	1910	7.8			X	X	X	X	X	X	X	X	X										
18	1437	5750	6.3	1950	8.1						Missed															
19		5740	5.9	1940	7.4			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
20		5710	7.0	1960	8.3			X	X	O	O	X	X	X	X	O	X	X	X	X	X	X	X			

TEST FIRING RESULTS

Radar AN/TPQ-31 Location Site 7 Date Dec. 1, 1972

Round	Time	1st Det R	1st Det Az	Last Det R	Last Det Az	Predicted Origin R	Predicted Origin Az	Target Track 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
21		5740	5.7	1930	8.3	5685	6500M	X	X	X	X	X	X	O	X	X	O	X	X	X	X					
22		5770	6.3	1970	8.0	5720	7350M	X	X	X	X	O	O	X	X	X	X	X	X	X	X					
23		5750	6.8	1980	7.9						MISS															
24		5660	5.9	2000	4.1	5640	6650M	X	X	X	X	X	X	X	X	O	X	X	X	X	X					
25		5700	6.3	1780	4.1	5670	7050M	X	X	O	X	X	X	X	X	X	X	X	X	X	X					
26	1515	5710	6.6	1710	4.8	5665	7600M	X	X	X	O	X	X	X	X	X	X	X								

RADAR AN/TPQ-31 LOCATION Site #7 DATE 4 Dec 72

TEST FIRING RESULTS

RD	TIME	1ST AZ (mils)	1ST RG (Km)	LAST AZ (mils)	LAST RG (Km)	PREDICTED ORIGIN AZ (mils)	PREDICTED ORIGIN RG (Km)	PRINTS 1 2 3 4 5 6 7 8 …	60° CHARGE
1	1010					NOT SEEN			0
2	1020					NOT SEEN			0
3	1023					ADJUSTING RADAR			4
4	1032					ADJUSTING RADAR			4
5	1037	5770	6.7	5915	4 2	5760	6.95		8
6	1041	5690	6 8	5970	4 2	5650	6.950		8
7	1045	5660	7.0	5720	6.3	5650	7.05	[illegible]	1
8	1046	5630	6.9	5680	4.8	5625	7.15		1
9	1047	5620	7 0	5690	5 8	5610	7100		2
10	1049	5650	7 0	5750	6 1	5640	7 100		2
11	1050	5740	7 1	6720	5.8	GOT 5" GUN AND MORTAR HIT		Same Time No Data	3
12	1052	5640	6 9	5720	5 6	5630	7050		3
13	1053	5650	6 9	5760	5 2	5645	7 070		5
14	1054	5660	6.9	5770	5 2	5640	7 050		5
15	1055	5620	6.9	5770	5 0	5620	7 05		6
16	1056	5655	7 0	5790	4.9	5655	7 15		6
17	1057	5650	6 0	5850	4.7	5640	6.13		7
18	1058	5670	6 8	5810	5 0	5670	6 95		7
19									
20									
21									
22									
23									
24									
25									

RADAR: AN/TPQ-31 LOCATION Site #7 DATE 6 Dec 72

TEST FIRING RESULTS

		1ST		LAST		PREDICTED ORIGIN		PRINTS	45° 65° QE
RD	TIME	AZ (mils)	RG (Km)	AZ (mils)	RG (Km)	AZ (mils)	RG (KM)	1 2 3 4 5 6 7 8 9 ...	CHARGE
1	1035	5650	6.6	5930	3.7	5647	6.64		8
2	1040	5670	7.0	5930	3.7	5670	7.00		8
3	1045	5680	7.3	5900	3.9	5650	7.02		8
4	1050	5690	6.5	5930	3.7	5685	6.90		8
5	1055	5670	6.8	5920	3.6	5665	6.90		8
6	1100	5570	9.0	5890	3.9	No plot was made	Operator	picked up clutter for round	8
7	1105	5650	6.8	5950	3.7	5650	7.05		8
8	1110	5660	6.5	5940	3.6	5655	6.60		8
9	1116	5680	6.8	5960	3.7	5675	6.90		8
10	1122	5660	6.9	5960	3.7	5670	7.12		8
11	1127	5650	7.0	5960	3.9	5645	7.10		8
12	1132	5650	6.5	5960	3.85	5645	6.90		8
13	1134	5660	6.9	5990	3.8	5655	7.00		8
14	1136	5660	6.4	6000	3.9	5650	7.00		8
15	1138	5700	6.75	5990	3.9	5695	6.85		8
16	1141	5660	6.7	5990	3.85	5600	6.80		8
17	1143	5670	6.7	5990	3.9	5665	6.80		8
18	1146	5670	6.5	6100	3.85	5660	6.60		8
19	1148	5670	6.5	6000	3.85	5670	6.70		8
20	1150	5680	6.9	6000	3.85	5675	7.100		8
21	1316	5700	6.5	5530	5.1	5685	6.90		8
22	1318	5655	6.8	5940	4.3	5643	6.90		8
23	1321	5650	6.9	5970	4.3	5645	7.00		8
24	1324	5670	6.6	5980	4.3	5660	6.7		8
25	1328	5660	6.4	5810	5.2	5655	7.0		6 63
26	1330	5670	6.4	5820	5.1	5665	6.97		6 63

RADAR AN/TPQ-31 LOCATION Site #7 DATE 7 Dec 72

TEST FIRING RESULTS

RD	TIME	1ST AZ (Mils)	1ST RG (Km)	LAST AZ (Mils)	LAST RG (Km)	PREDICTED ORIGIN AZ (Mils)	PREDICTED ORIGIN RG (Km)	PRINTS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25	65 CHARGE
1	1014	5640	6.8	6000	3.3	5620	7.55	xxxooxx	6
2	1016	5650	6.5	3730	4.8	5635	7.3	xxoooxx	6
3	1018	5650	6.9	6240	2.5	5630	7.5	xooxxxxxx	6
4	1020	5690	6.6	5780	4.6	5655	6.75	xxoxooooxoxxx	6
5	1022	5650	6.8	5750	4.9	5645	6.95	xoxxxooooooxxx	6
6	1023	5650	7.0	5740	4.9	5645	7.5	xxxxxoooxooxxx	6
7	1023	5640	7.0	5780	4.8	5630	7.5	xooxxooooooxxxx	6
8	1025	5680	6.7	5750	4.9	5675	7.15	ooxxxoooooxxx	6
9	1030	5680	6.5	5780	4.8	5673	6.95	ooooxxoooooooxxxx	6
10	1032	5650	7.0	5750	4.9	5645	7.45	oxxooooooooxxxxxx	6
11	1035	5670	6.6	5730	4.8	5665	7.3	oxxoooxooxxx	6
12	1056	5630	6.9	5750	4.8	5660	7.0	xxxxoooooooxx	6
13	1058	5680	6.4	5750	4.9	5675	6.55	ooxoooooxooxx	6
14	1100	5670	6.8	5760	4.8	5665	7.13	xxoxoooooooxxx	6
15	1102	5650	6.6	5740	3.1	5650	6.63	ooxxxooxxxoooox	6
16	1104	5670	6.9	5750	4.9	5620	7.1	xxxxxooxxxooxx	6
17	1106	5670	6.4	5760	4.9	5665	6.9	ooxxxooxoxoxo	6
18	1108	5660	6.9	5770	5.0	5650	7.1	xxxxoooxooxooxxx	6
19	1110	5670	6.9	5750	4.8	5670	6.95	xxxxooooooooxxx	6
20	1112	5650	6.9	5750	4.9	5650	6.93	xoxxxooxoxooxx	6
21	1115	5650	6.9	5750	4.9	5650	6.98	xxxxxooooxoooxx	6
22	1118	5670	6.8	5770	4.8	5650	6.9	xxxxxooxoxooxxx	6
23	1121	5660	6.9	5760	4.9	5654	7.0	xxxxxoxxooooox	6
24	1124	5670	6.8	5730	4.9	5650	6.87	xxxxoxooxxoooox	6
25									6

RADAR AN/TPQ-31 LOCATION Site #7 DATE 7 Dec 72

TEST FIRING RESULTS

		1ST		LAST		PREDICTED ORIGIN		PRINTS	25°
RD	TIME	Mils AZ	Km RG	Mils AZ	Km RG	Mils AZ	Km RG	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25	CHARGE
1	1125	5700	58	5810	42	5690	589	OOXXXXXX	8
2	1128	5730	35	5860	42	5730	567	OOXXXXXXX	8
3	1130	5720	33	5850	42	5720	56	OOOXOXXXX	8
4	1133	5730	33	5560	38	5735	56	OOOXXXXXOX	8
5	1135	5730	55	5830	42	5743	54	OOOXXXXXX	8
6	1138	5740	31	5840	42	5731	53	OOOOXXXX	8
7	1140	5620	69	5830	42	5670	705	XOOOXOXXXX	8
8	1142	5720	60	5830	38	5720	611	OOXXXXXXXXX	8
9	1345	5760	54	5840	42	5759	574		8
10	1347	5720	58	5910	40	5715	59	XOOXXXXXXXXX	8
11	1349	5690	58	5820	43	5655	56	XOOXXXXXXX	8
12	1351	5710	38	5890	41	5700	59	OXOXXXXXXX (Out) CLUTTER FILTER	8
13	1353	5760	60	5820	42	5765	61	OOXXXXXXX (IN)	8
14	1358	5780	53	5830	42	5723	54	OOOOXXXXXX (Out)	8
15	1359	5700	57	5830	42	5695	58	OOXXXXXXX (IN)	8
16	1358	5660	66	5900	37	5555	67	XXOOOXOXXXXXXOXX	8
17	1400	5665	64	5950	35	5660	67	OXXXXXOXXXXXOXXXX	8
18	1402	5650	68	5930	35	5645	69	XXOOXXXXXXXXOXX	8
19	1405	5710	62	5920	35	5710	63	OOXXXXOXXXXXOXXX	8
20	1407	5700	64	5900	36	5695	65	OXOXOOXXXXXXOXX	8
21	1409	5710	68	5890	35	5705	69	XOOXXXOXXXXXXOXX	8
22	1411	5680	64	5920	35	5675	65	OXOXXXOXXXXXOXX	8
23	1413	5670	69	5910	36	5665	70	XXOOXOOOOXXXXOXX	8
24	1415	5700	60	5920	37	5695	61	OOXXXOXXXXXOXX	8
25	1417	5690	66	5960	38	5685	67	XOXXXOXXXXOXXX	8

RADAR AN/TPQ-31 LOCATION Site #7 DATE 1 DEC 12

TEST FIRING RESULTS

		1ST		LAST		PREDICTED ORIGIN		PRINTS	25°
RD	TIME	AZ (Mils)	RG (Km)	AZ (Mils)	RG (Km)	AZ (Mils)	RG (Km)	1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5	CHARGE
26	1419	5690	66	5940	36	5655	67	XXOXXXXXXXXOXX	8
27	1420	5700	64	5920	37	5695	65	OXXXOXXXXXXXOXX	8
28	1424	5700	64	5890	38	5700	65	OXOXXXXXXXXOXX	8
29	1426	5680	68	5930	36	5680	69	XXXOOOXXXXXXOXX	8
30	1428	5690	64	5970	36	5685	65	OXOOOOXXXXXXXX	8
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									

RADAR AN/TPQ 31 LOCATION Site #7 DATE 7 DEC 79

TEST FIRING RESULTS

RD	TIME	1ST AZ (Mils)	1ST RG (Km)	LAST AZ (Mils)	LAST RG (Km)	PREDICTED ORIGIN AZ (Mils)	PREDICTED ORIGIN RG (Km)	PRINTS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25	65° CHARGE
1	1436	5640	69	5730	62	5640	69	XXXXXXOOX	2
2	1437	5640	69	5730	62	5635	70	XXXXXXXOOX	2
3	1439	5650	68	5710	62	5649	632	XXOXXXXX	2
4	1441	5650	69	5700	59	5650	69	XXXXXXOXXXX	2
5	1443	5640	69	5700	62	5640	69	XXOXXXXXX	2
6	1445	5640	69	5650	59	5635	69	OXXXXXXXOOOX	2
7	1447	5650	69	5715	62	5645	69	OXXXXXOOX	2
8	1449	5640	68	5700	60	5635	69	XXXXXXXXXX	2
9	1451	5640	68	5700	59	5635	69	XXXXXXXOXOXX	2
10	1453	5640	68	5700	62	5640	69	XOXOXXXXX	2
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									

Annex F - (Ft. Sill Test Data Analysis) to Report of AN/TPQ-31 Performance During Evaluation as a Hostile Weapon Locator

FT. SILL TEST DATA ANALYSIS

The prime analysis tool is the use of a computer simulation of each round fired. This allows reconstructing each shot to determine how the radar should have performed. The actual performance is then compared with the predicted performance. The statistics which were processed from the radar data provide a revealing insight to the performance of the radar for the Fort Sill trials.

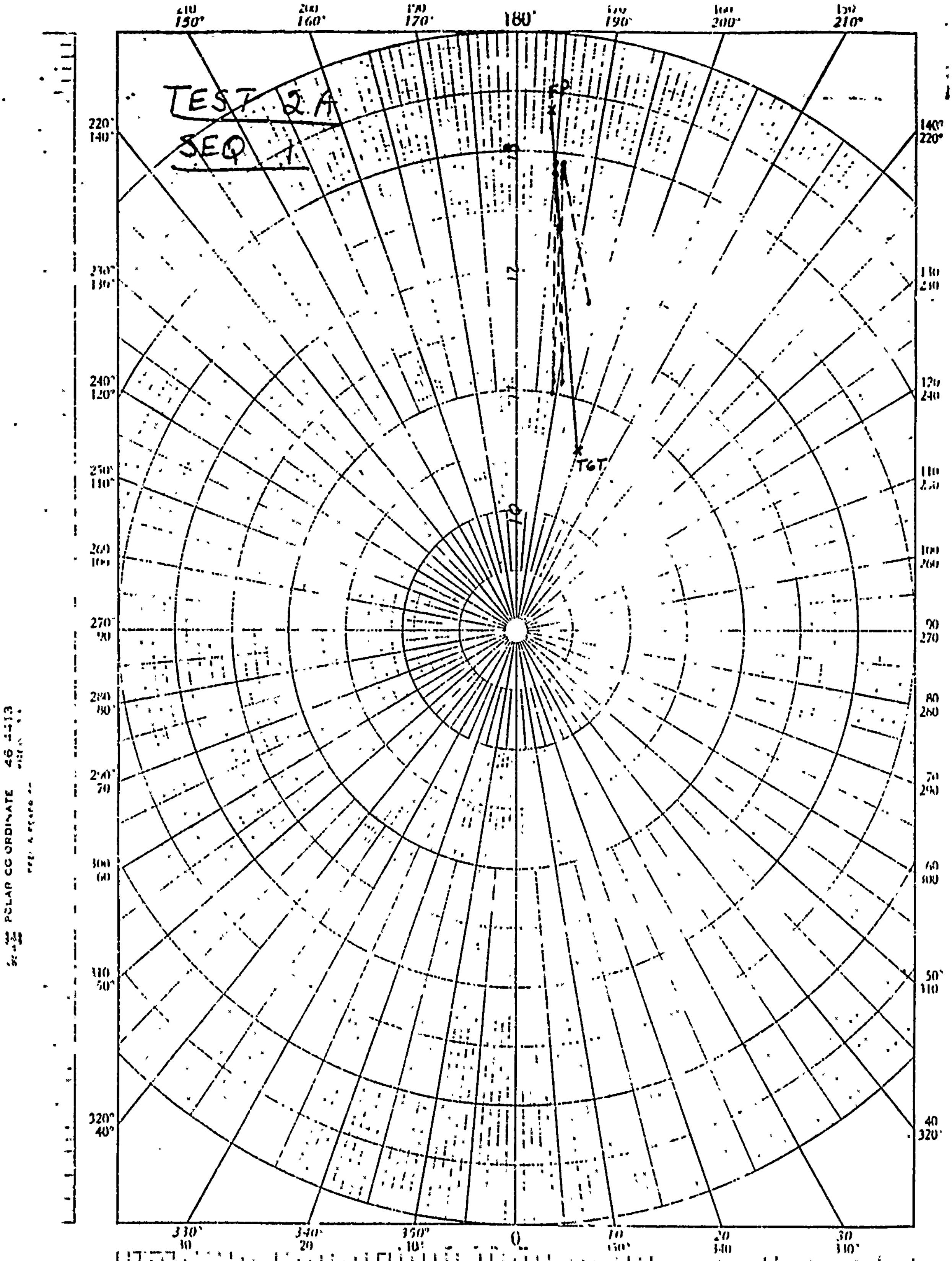
Each round was simulated and the projectile aspect and pitch angle, range, range rate, azimuth, elevation and normalized target size for each 2 second interval of the shot were derived. A value for each 2 second interval representing the predicted signal level above the MDS threshold was then determined using this information. This signal level was plotted vs time and provided a basis for a comparison of radar results with expectations. See Appendix 3, this Annex, for predicted detection curves.

Appendix 1 - (Polar Plots) to Annex F of Report of AN/TPQ-31 Performance During Evaluation as a Hostile Weapon Locator

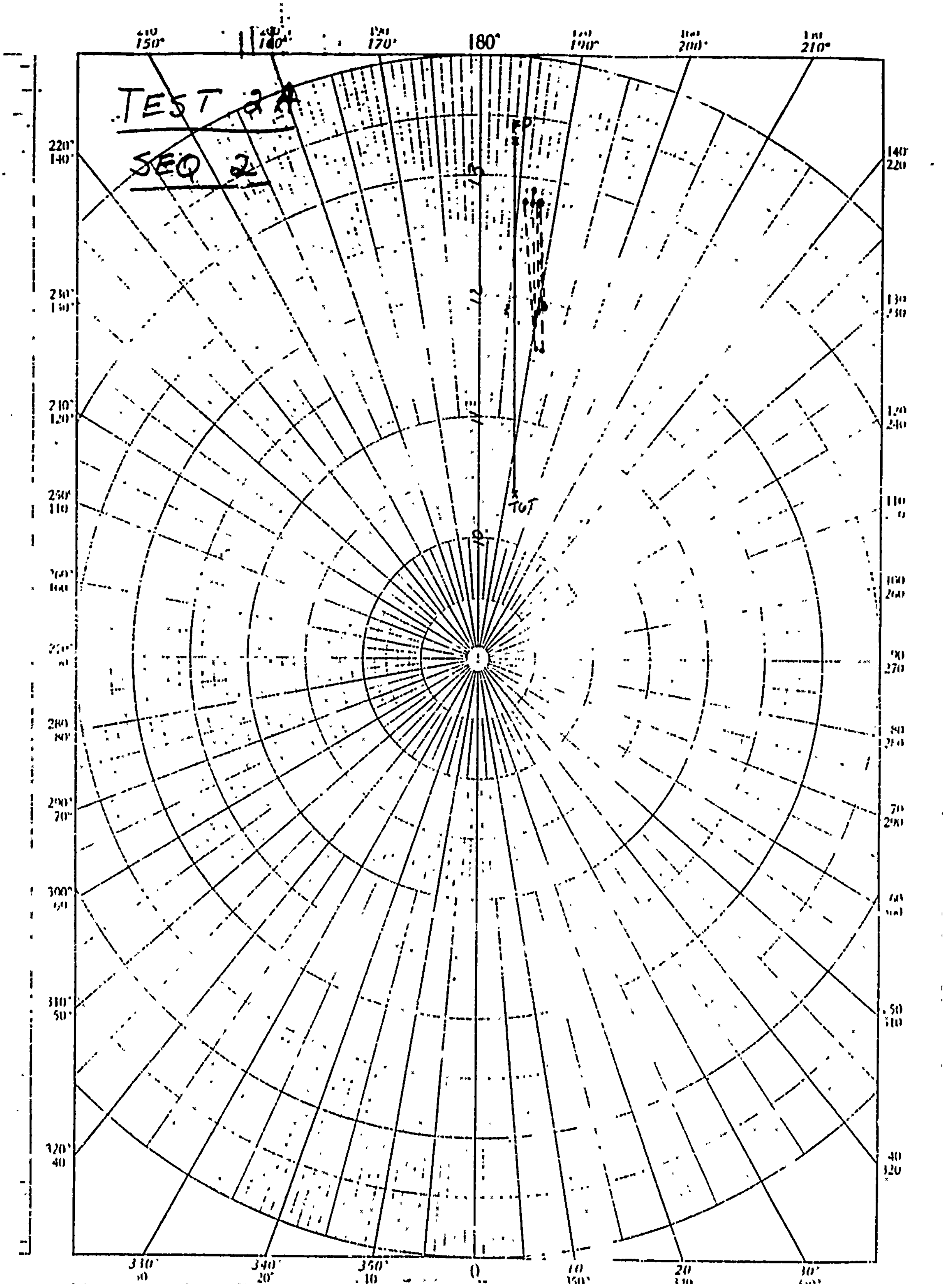
POLAR PLOTS

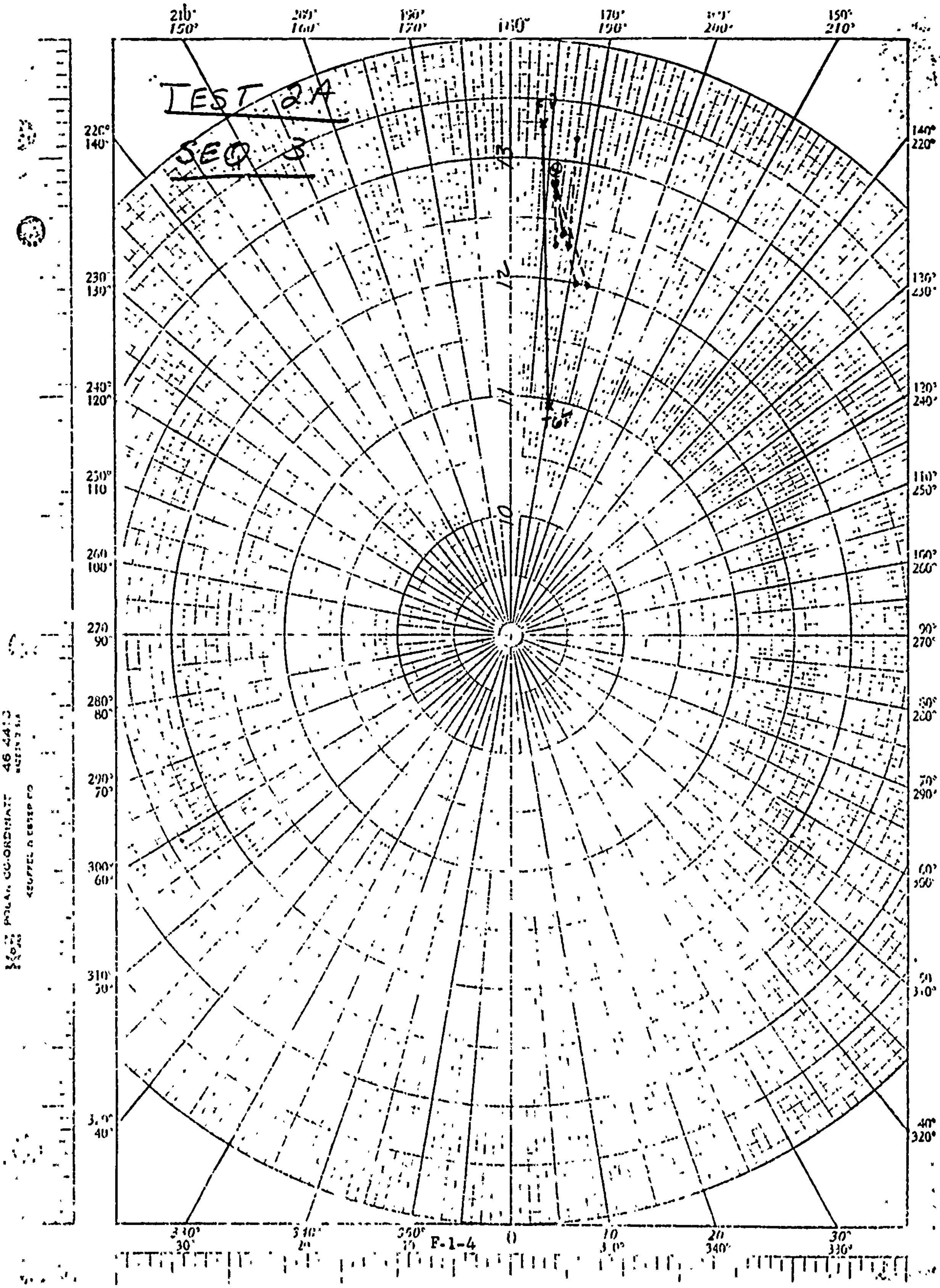
The following plots show in polar form the firing points and target points for each test. In addition, first looks and last looks are plotted with dashed lines connecting some of the points. This type of presentation allows a quick evaluation of the possibility of having tracked the wrong projectile. These plots also readily reveal the existence of any biases present in the radar data.

The displayed biases, in many cases, are caused by azimuth orientation errors that result from the manual boresite method used by the AN/TPQ-31. The use of an optical boresight telescope would help alleviate the biases attributable to azimuth orientation errors.

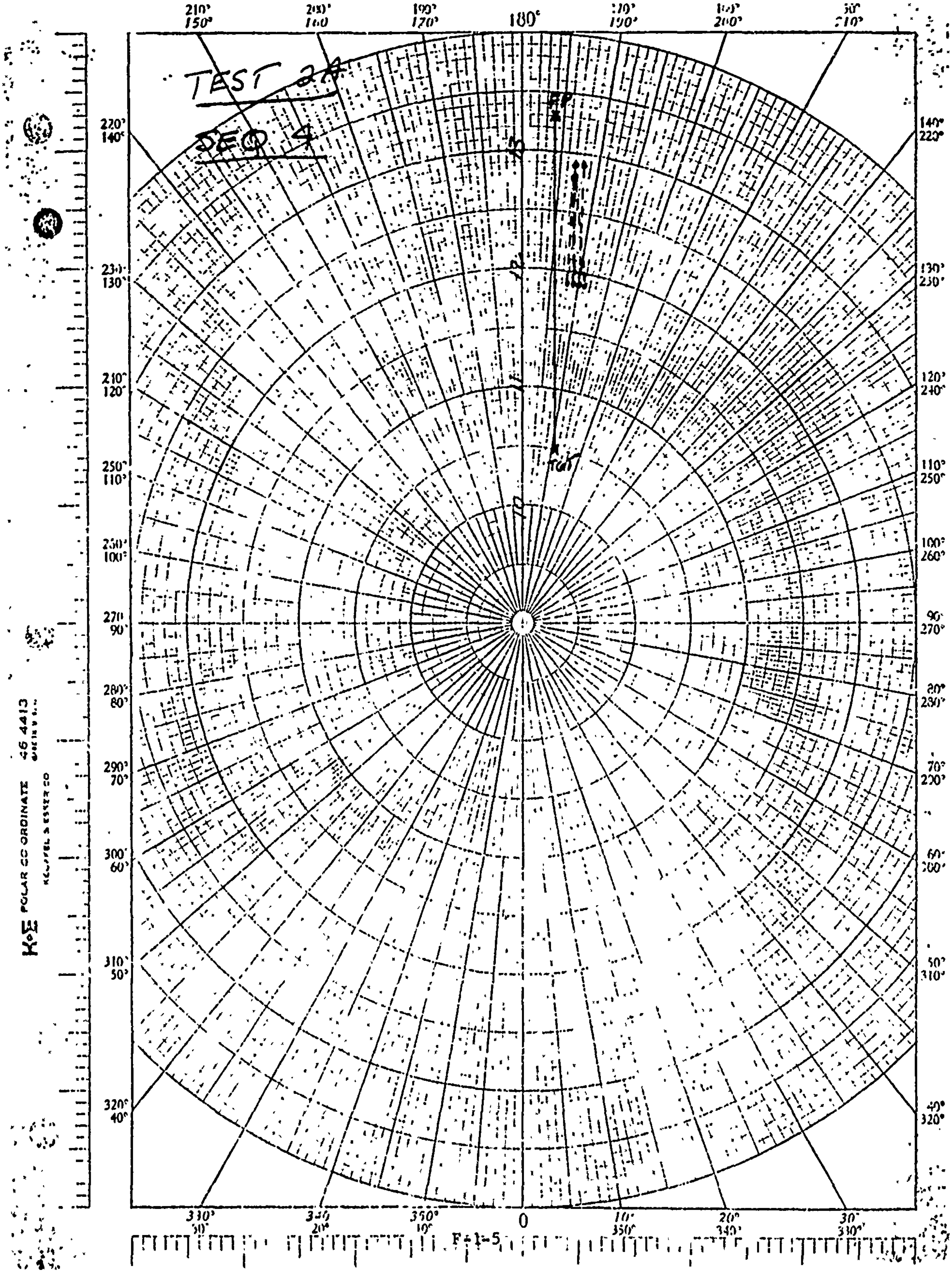


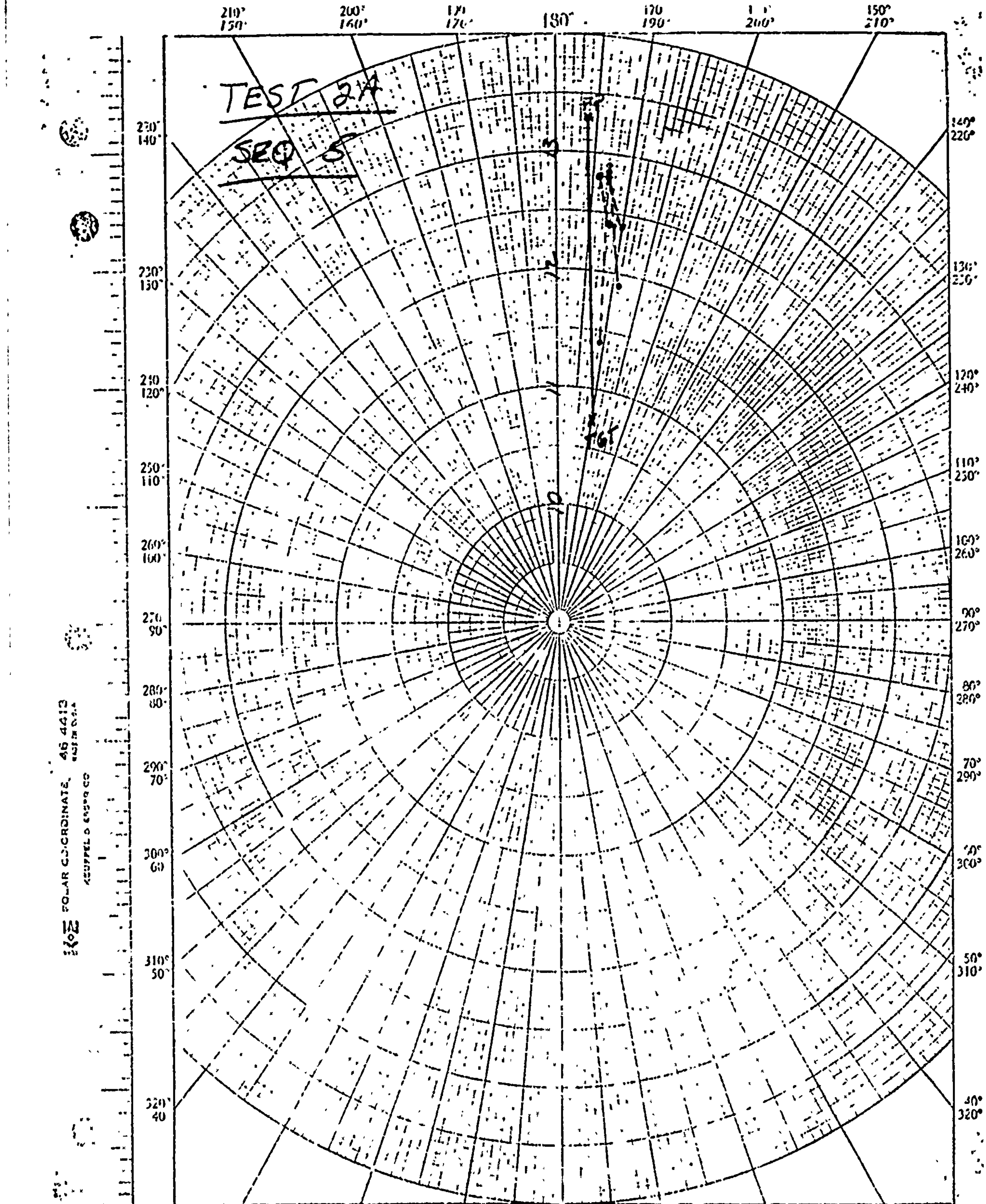
TEST 2A
SEQ 1
TGT
POLAR COORDINATE 46 4413


TEST 2A
SEQ 2
FD
TGT
150°
170°
180°
190°
200°
210°
330°
340°
350°
0
10
20
30°

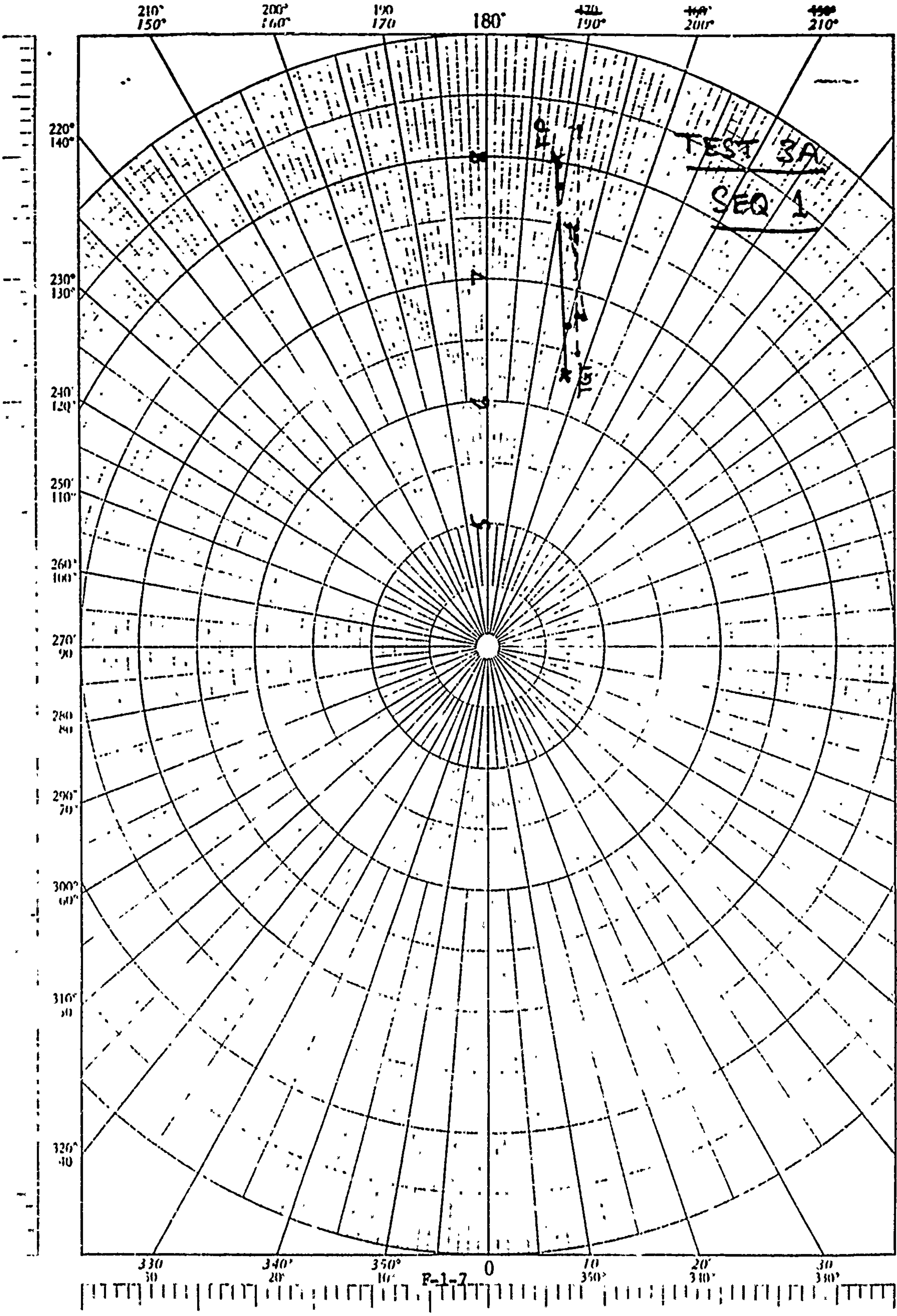


TEST 2A
SEQ 3

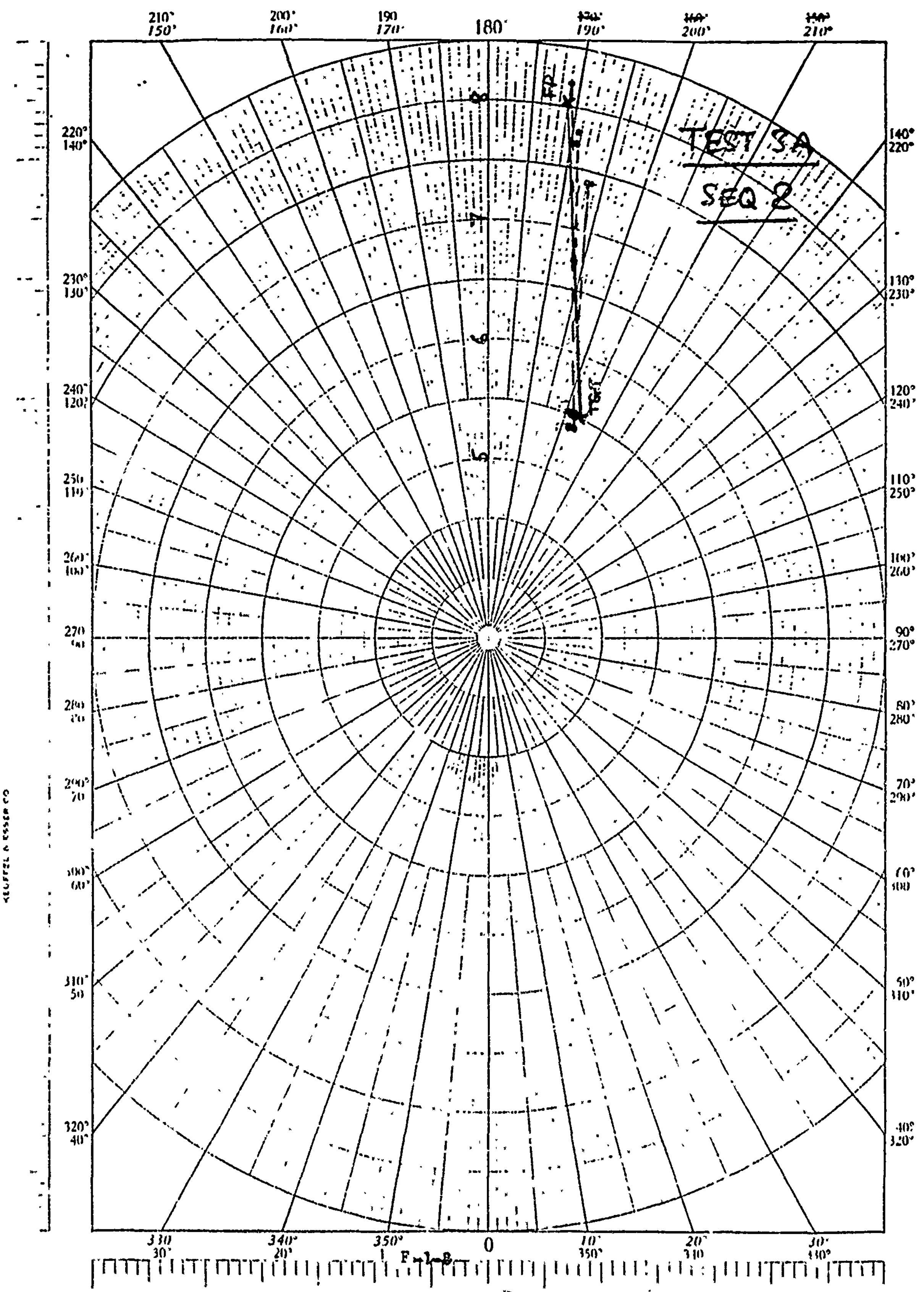

TEST 2A
SEQ 4
180°
0
F-1-5
K+E POLAR CO ORDINATE 46 4413
KEUFFEL & ESSER CO



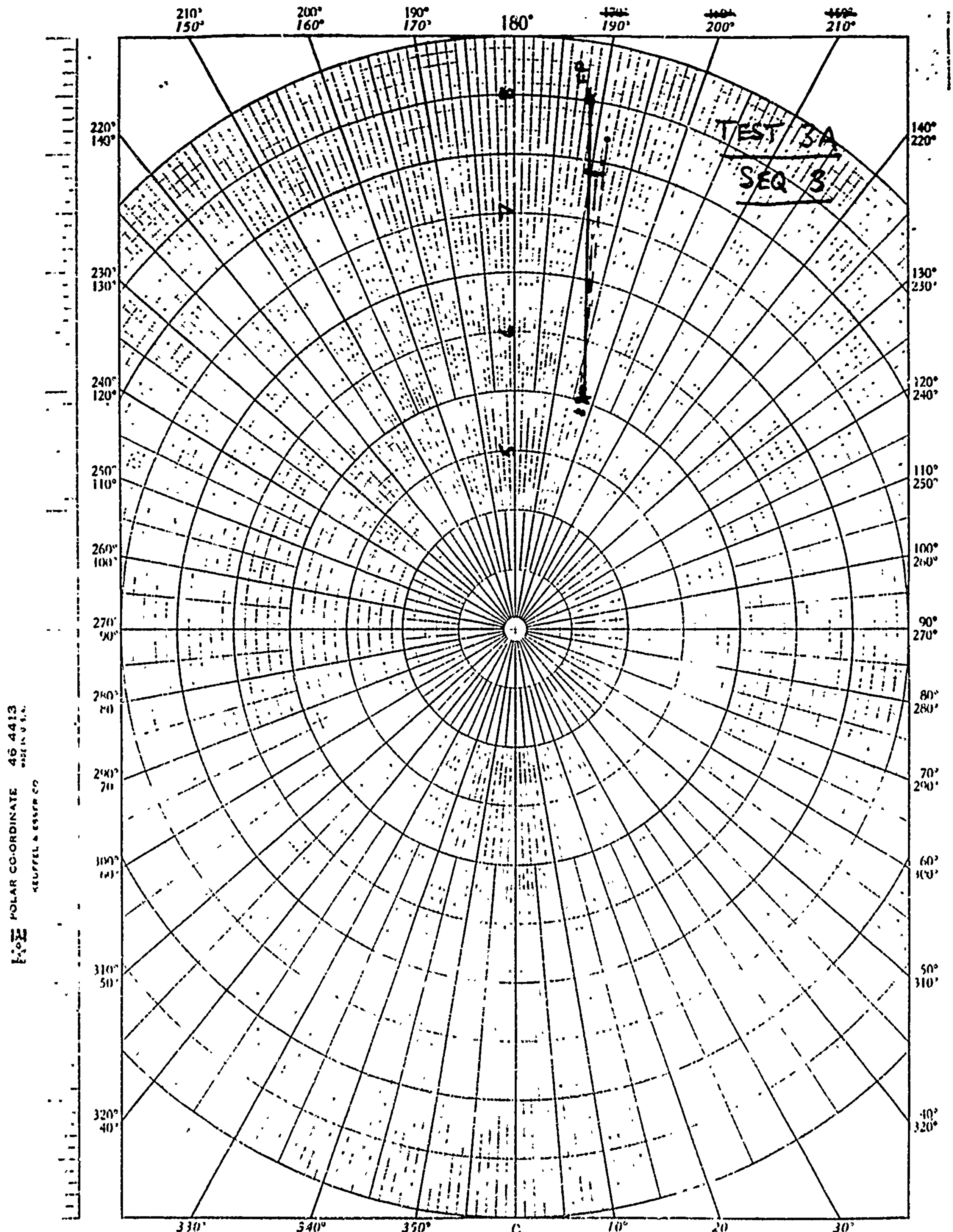
F-1-6



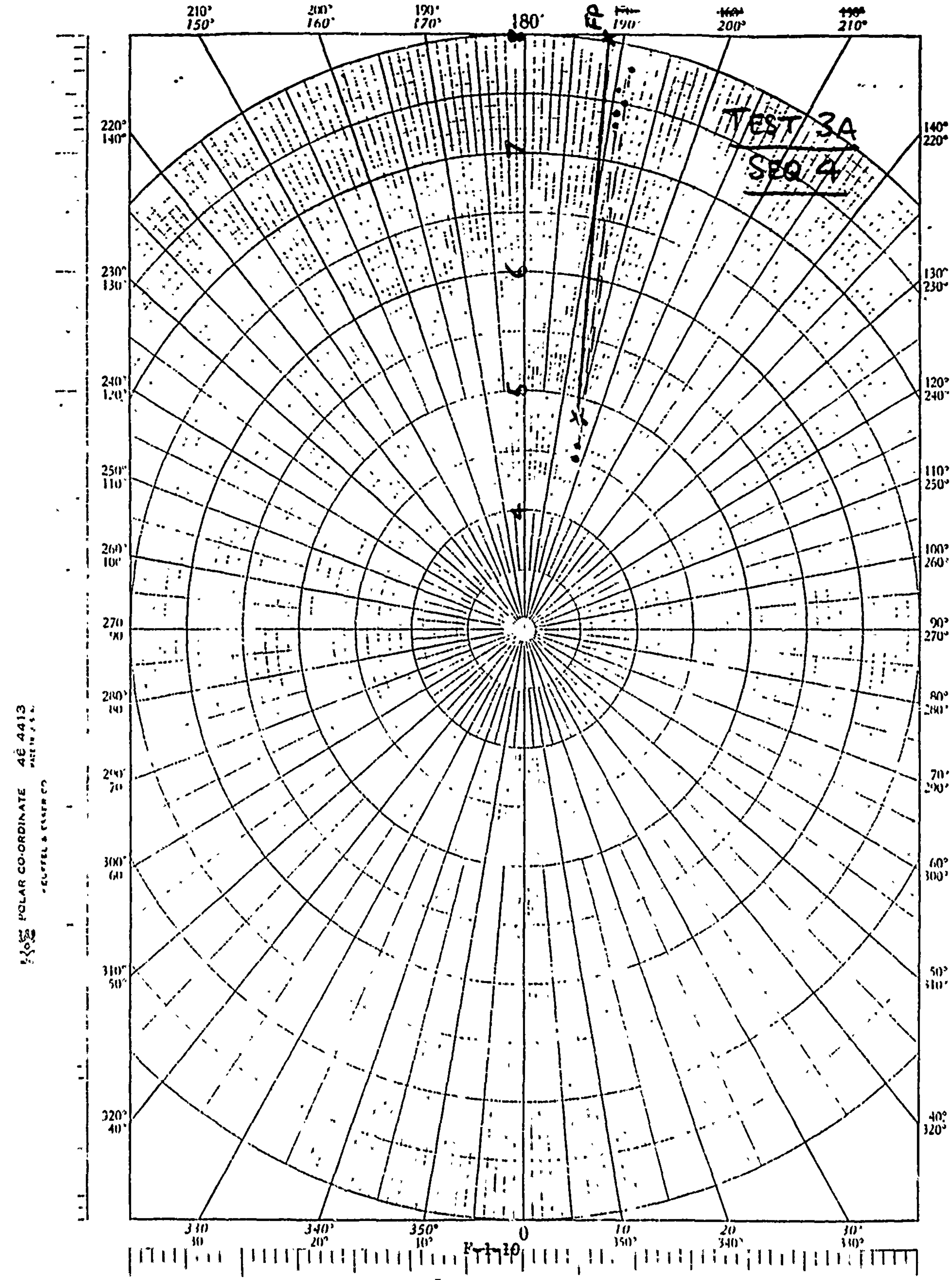
F-1-7



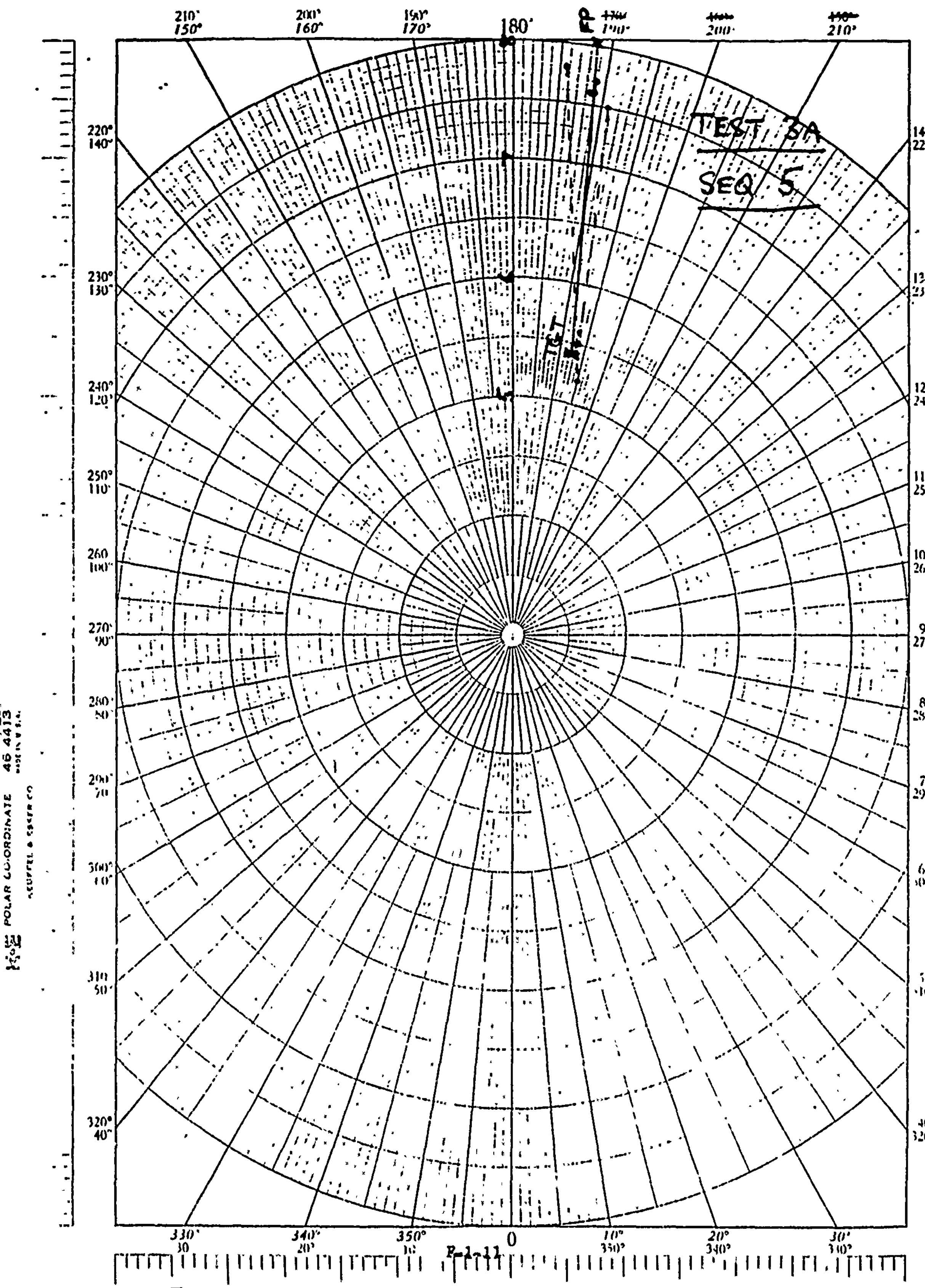
TEST 3A
SEQ 2
180°
FP
TGT
F-1-B
POLAR COORDINATE 46 4413
KEUFFEL & ESSER CO.

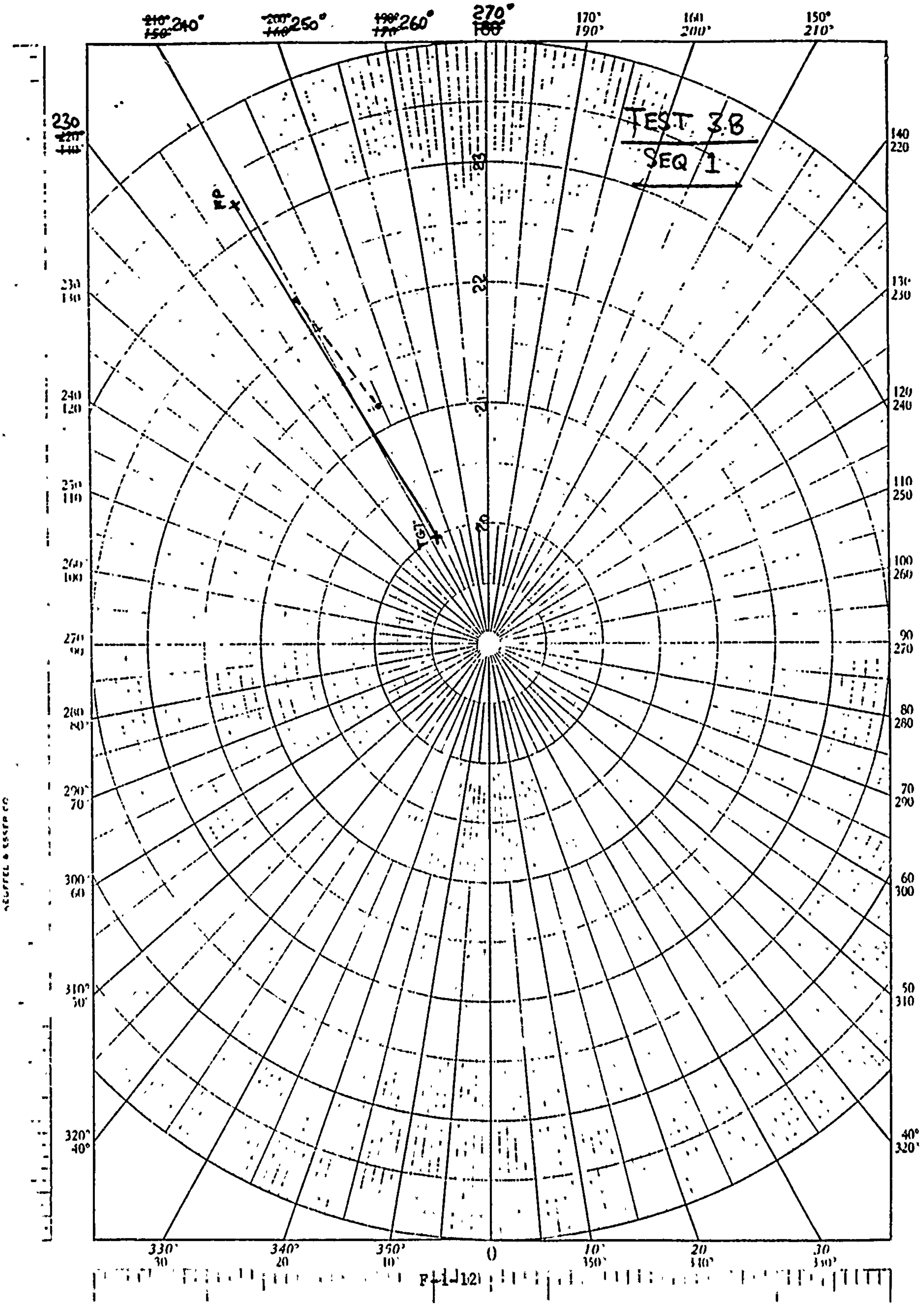


F-1-9

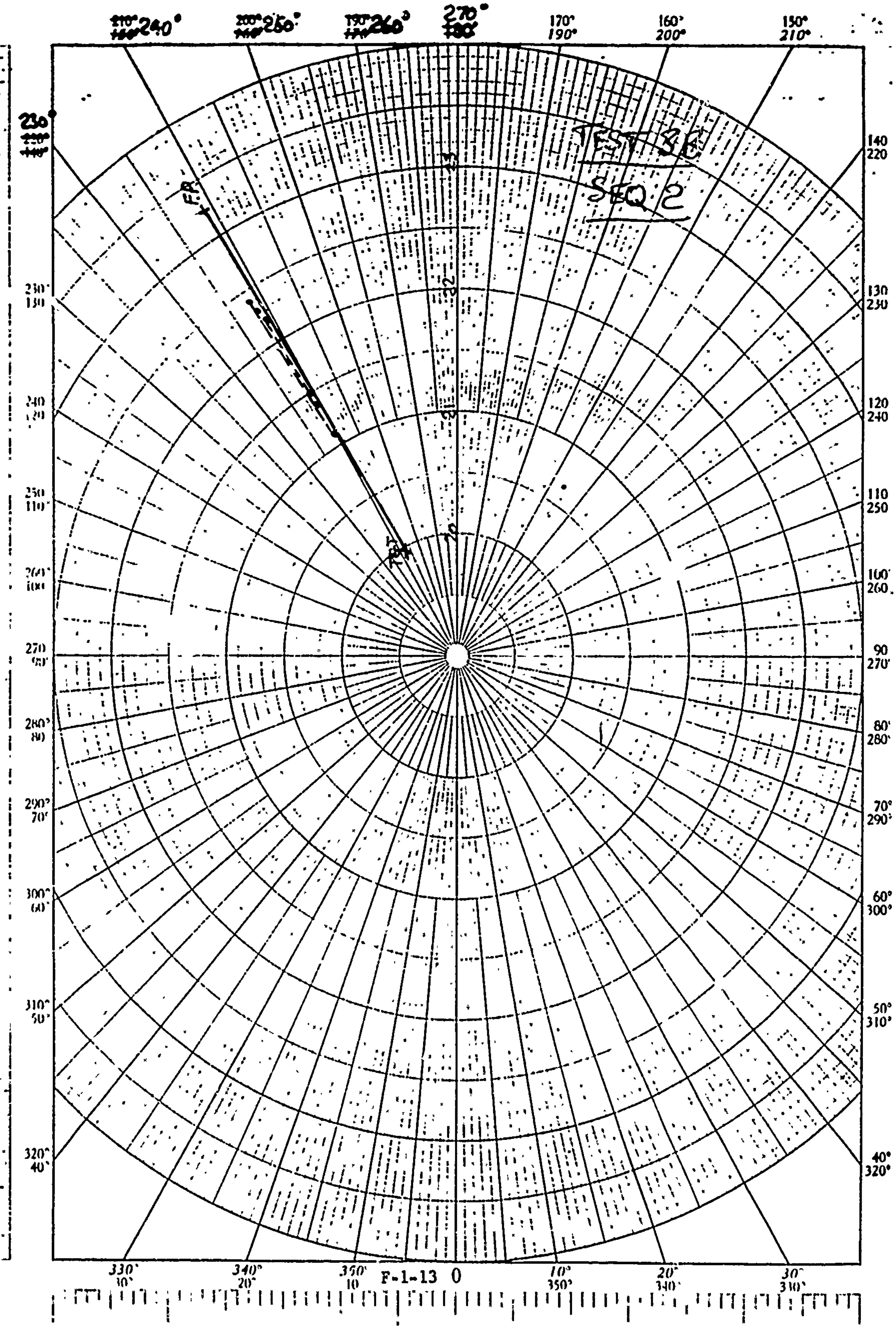

TEST 3A
SEQ 4
FP
180°
X
POLAR CO-ORDINATE 46 4413
KEUFFEL & ESSER CO.

F-1-10

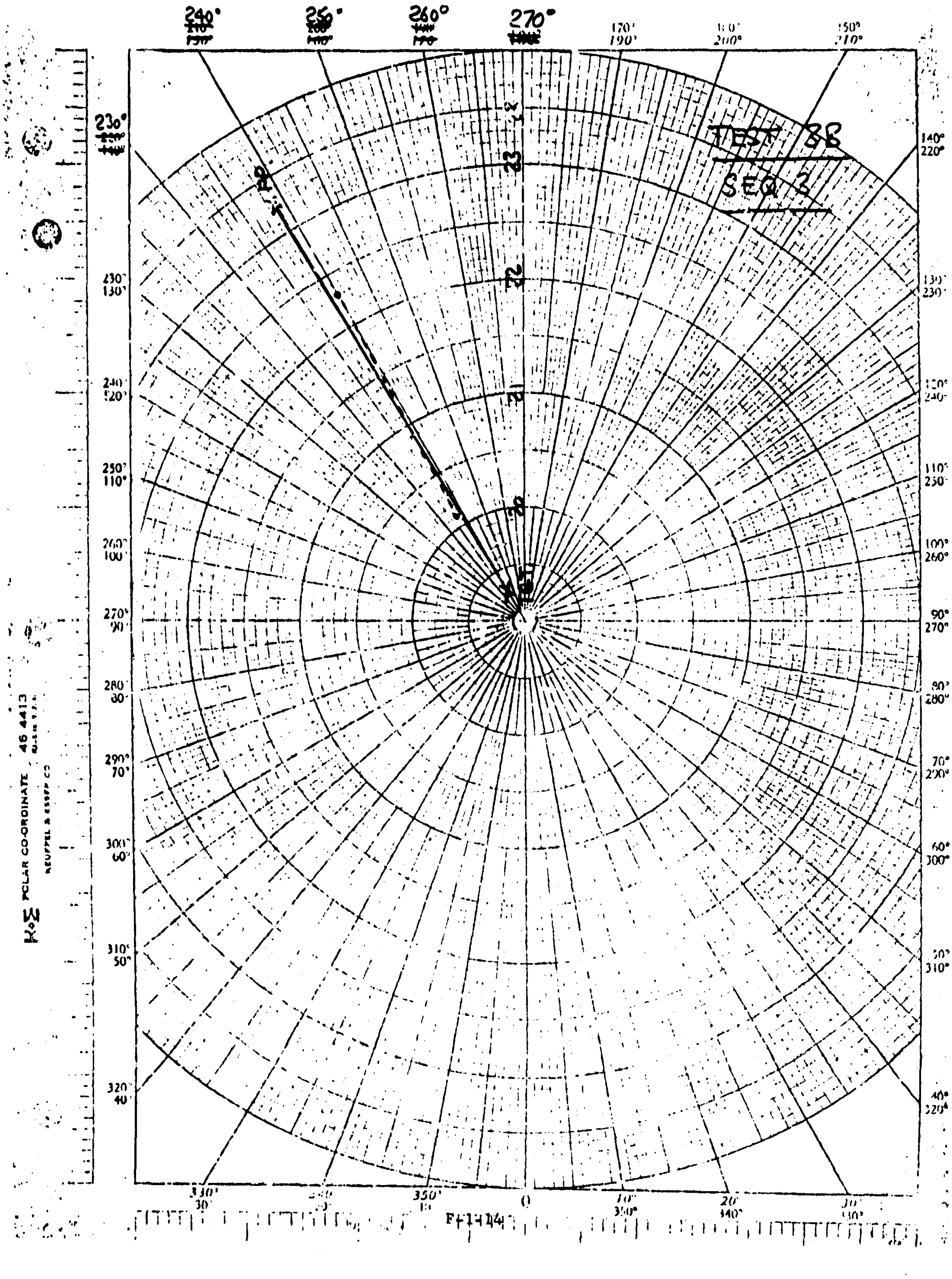

TEST 3A
SEQ 5
FP
TGT
POLAR COORDINATE 46 4413
KEUFFEL & ESSER CO.



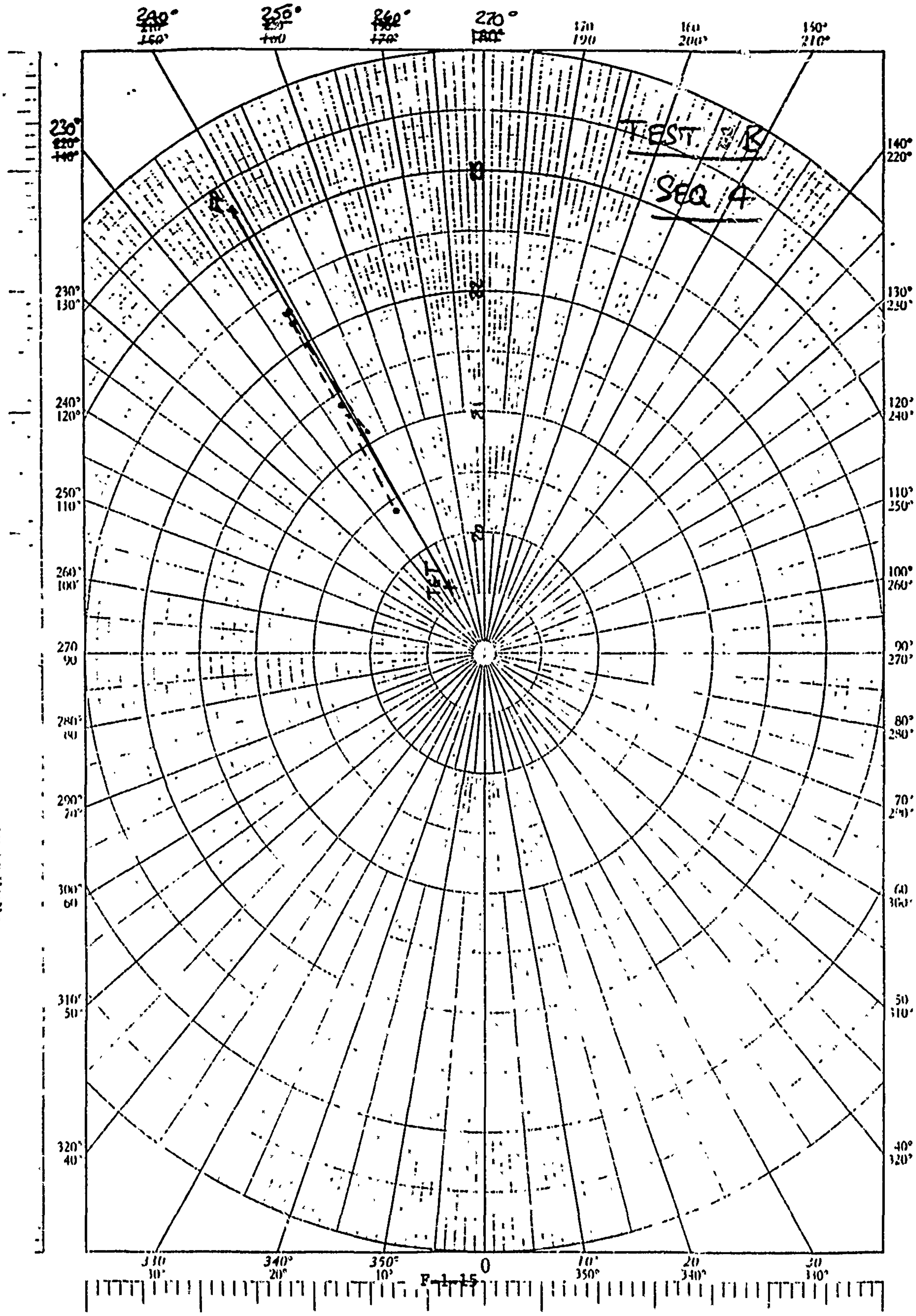
TEST 3B
SEQ 1
RP
TGT
240°
250°
260°
270°
170°
190°
160
200°
150°
210°
230
140
220
130
230
120
240
110
250
100
260
90
270
80
280
70
290
60
300
50
310
40°
320°
330°
30
340°
20
350°
10°
0
10°
350°
20
340°
30
330°



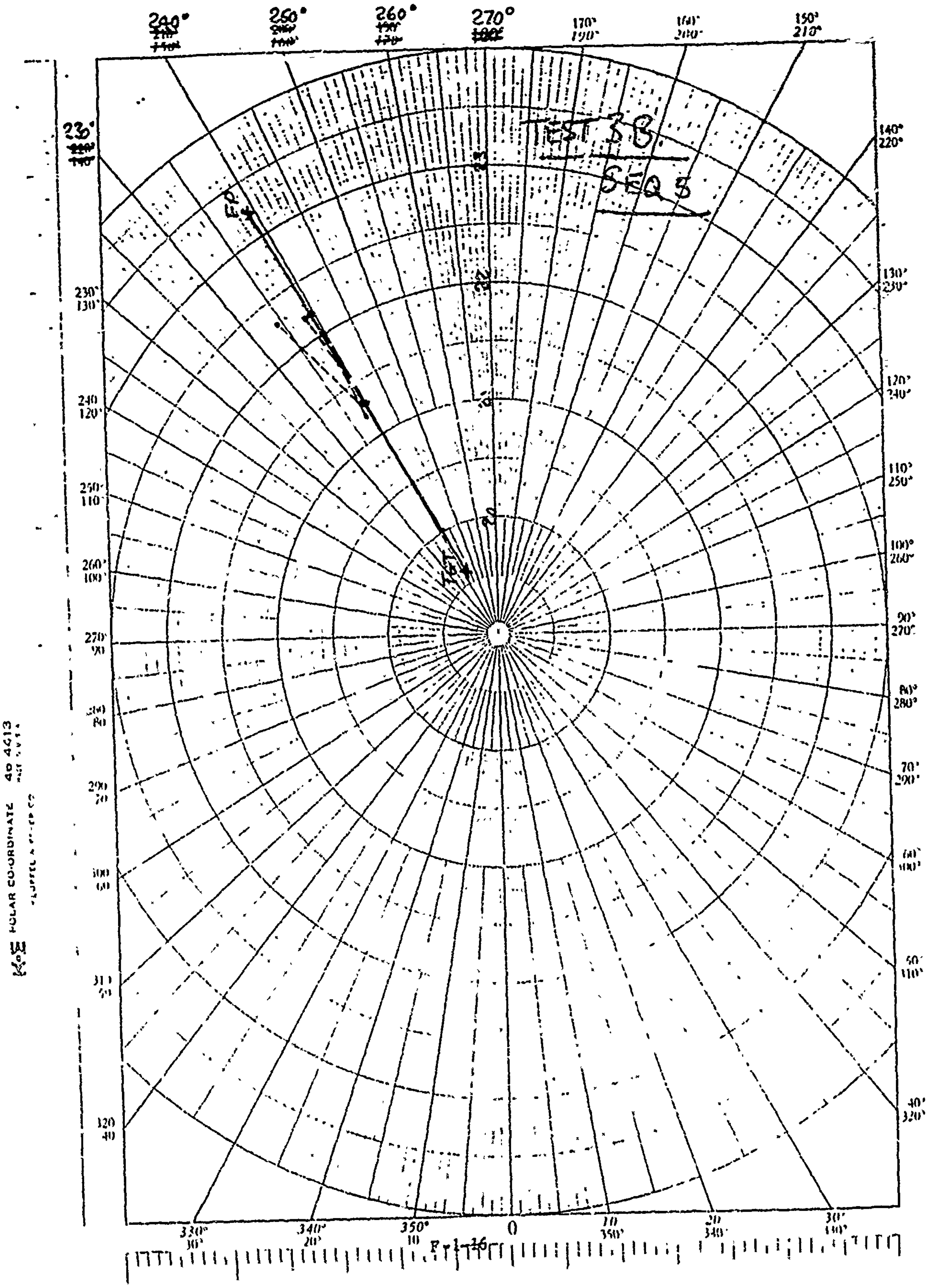
TEST 3B
SEQ 2
F.R.
F-1-13
POLAR CO ORDINATE 46 4413
KEUFFEL & ESSER CO.

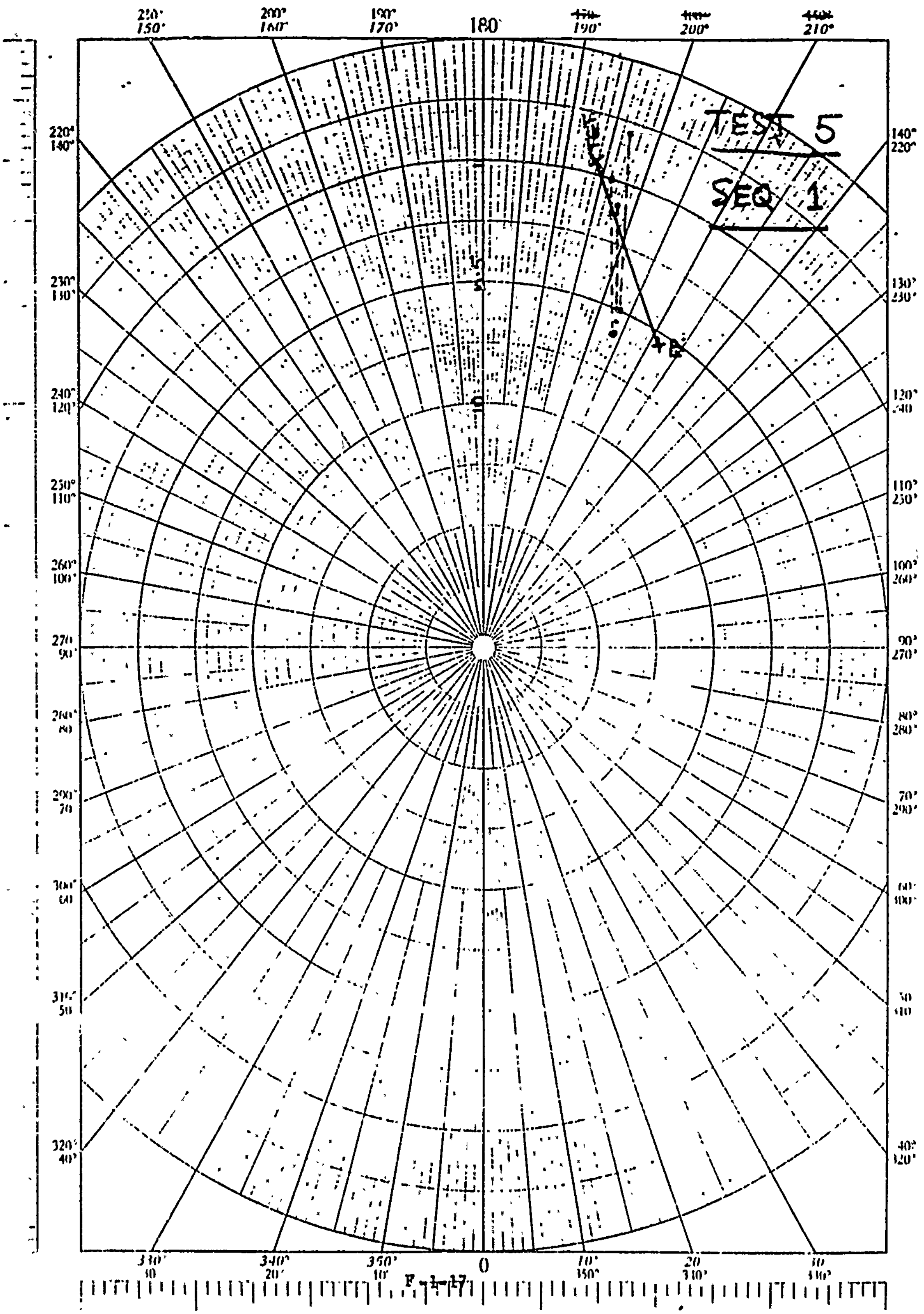


TEST 3B
SEQ 3
240°
250°
260°
270°
230°
K+E POLAR CO-ORDINATE 46 4413
KEUFFEL & ESSER CO.
F-14447



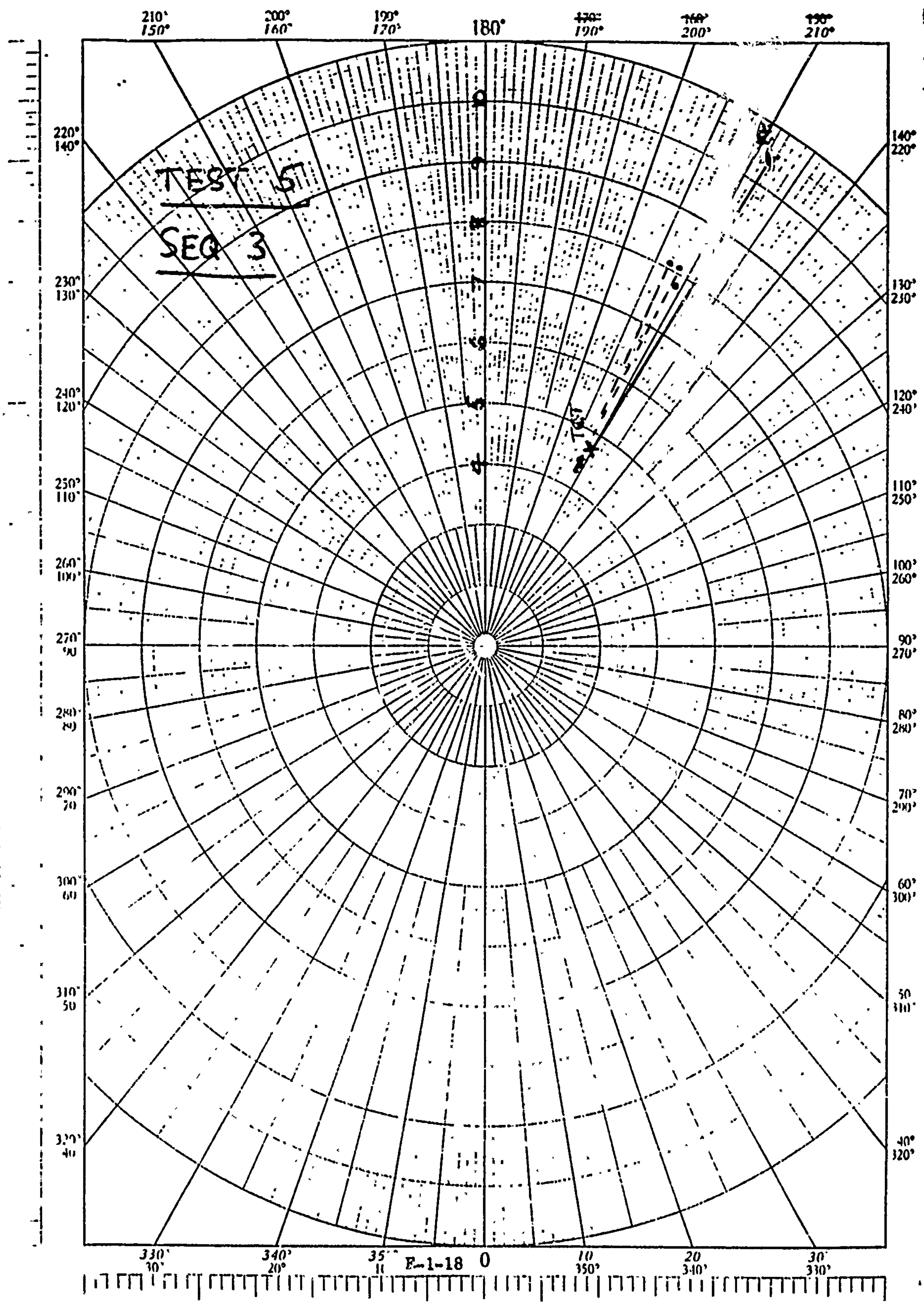
F-1-15

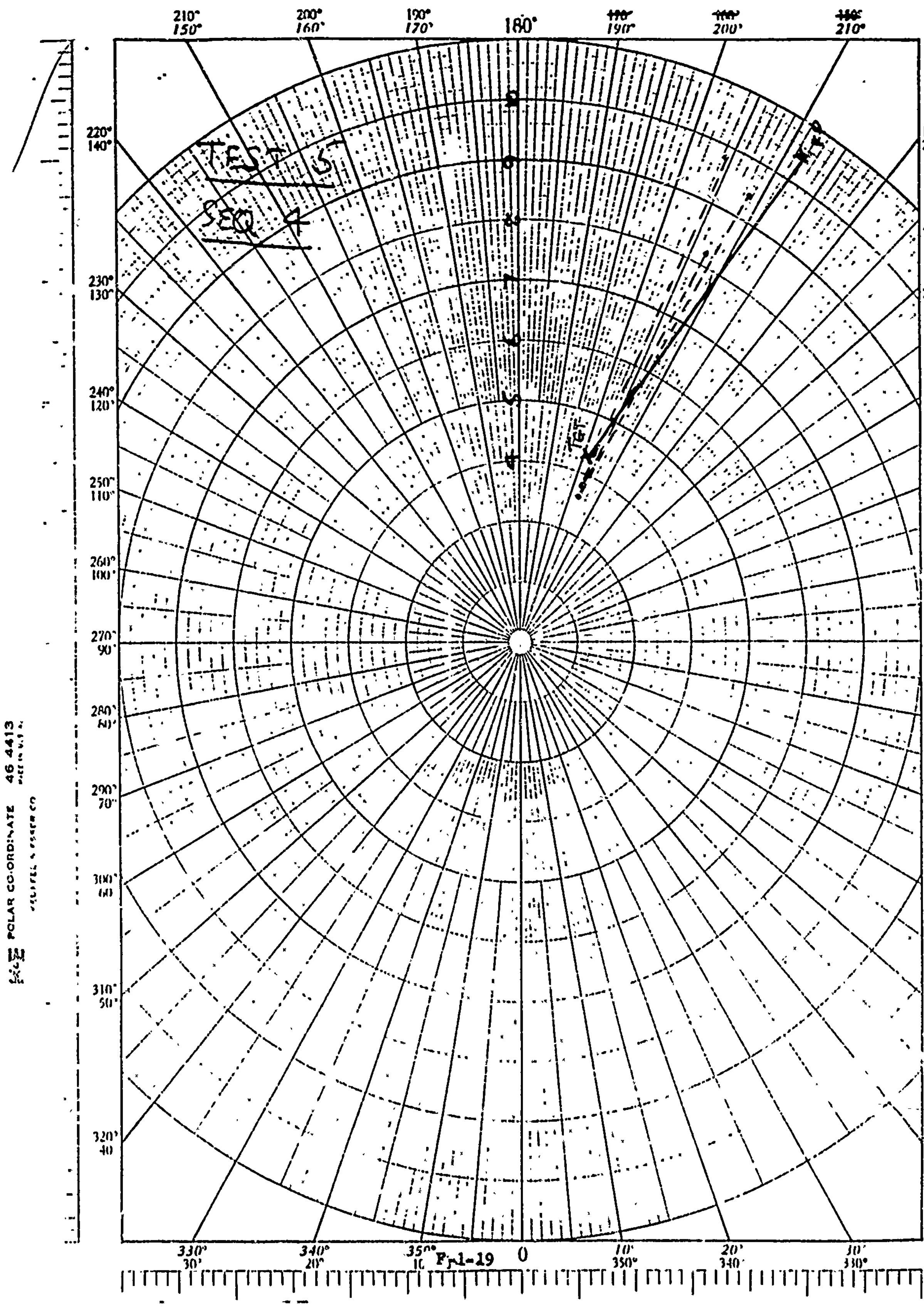

TEST 3B
SEQ 5
POLAR CO-ORDINATE 46 4613
F-1-16



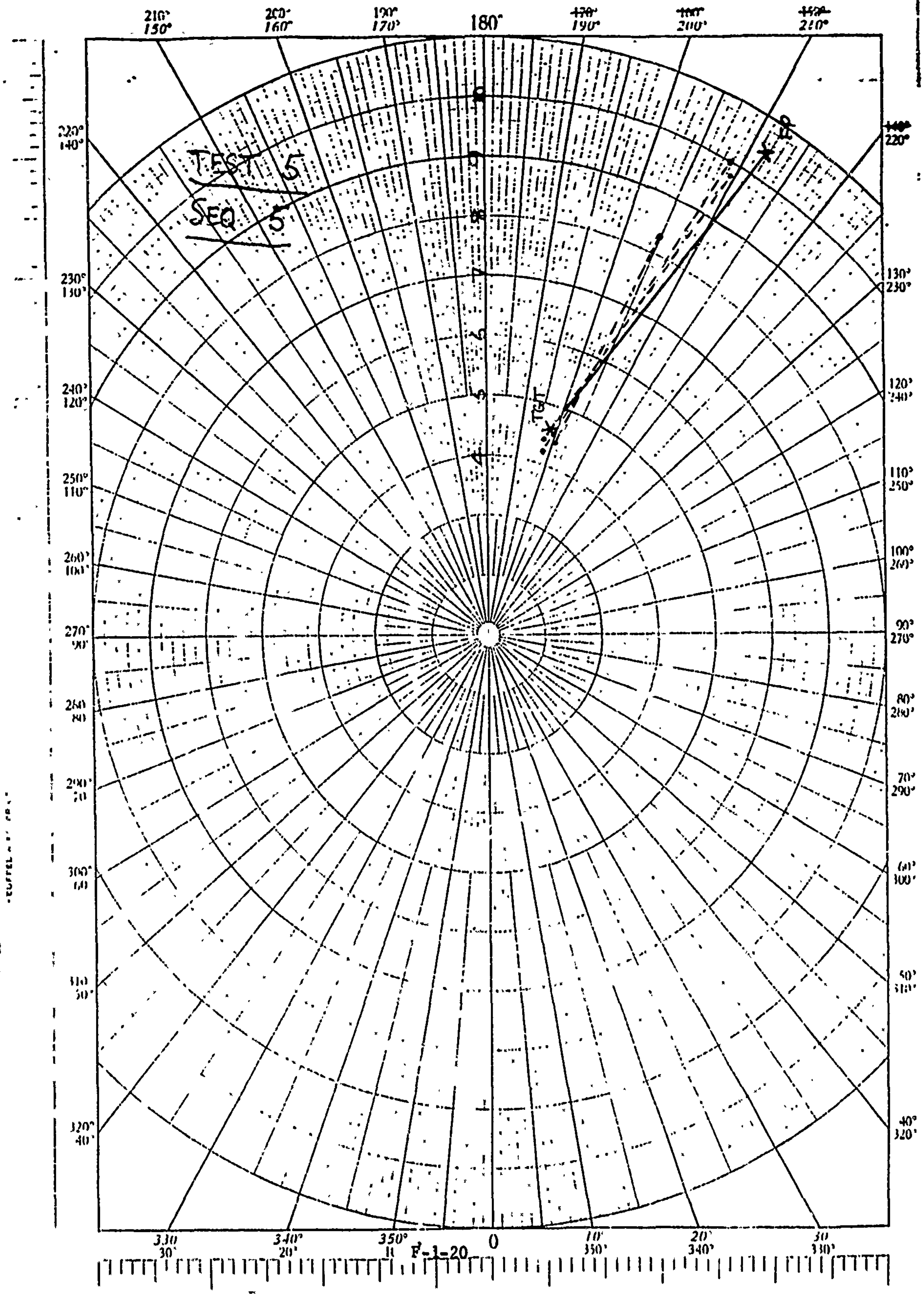
F-1-17

POLAR CO-ORDINATE 46 4413
KEUFFEL & ESSER CO.

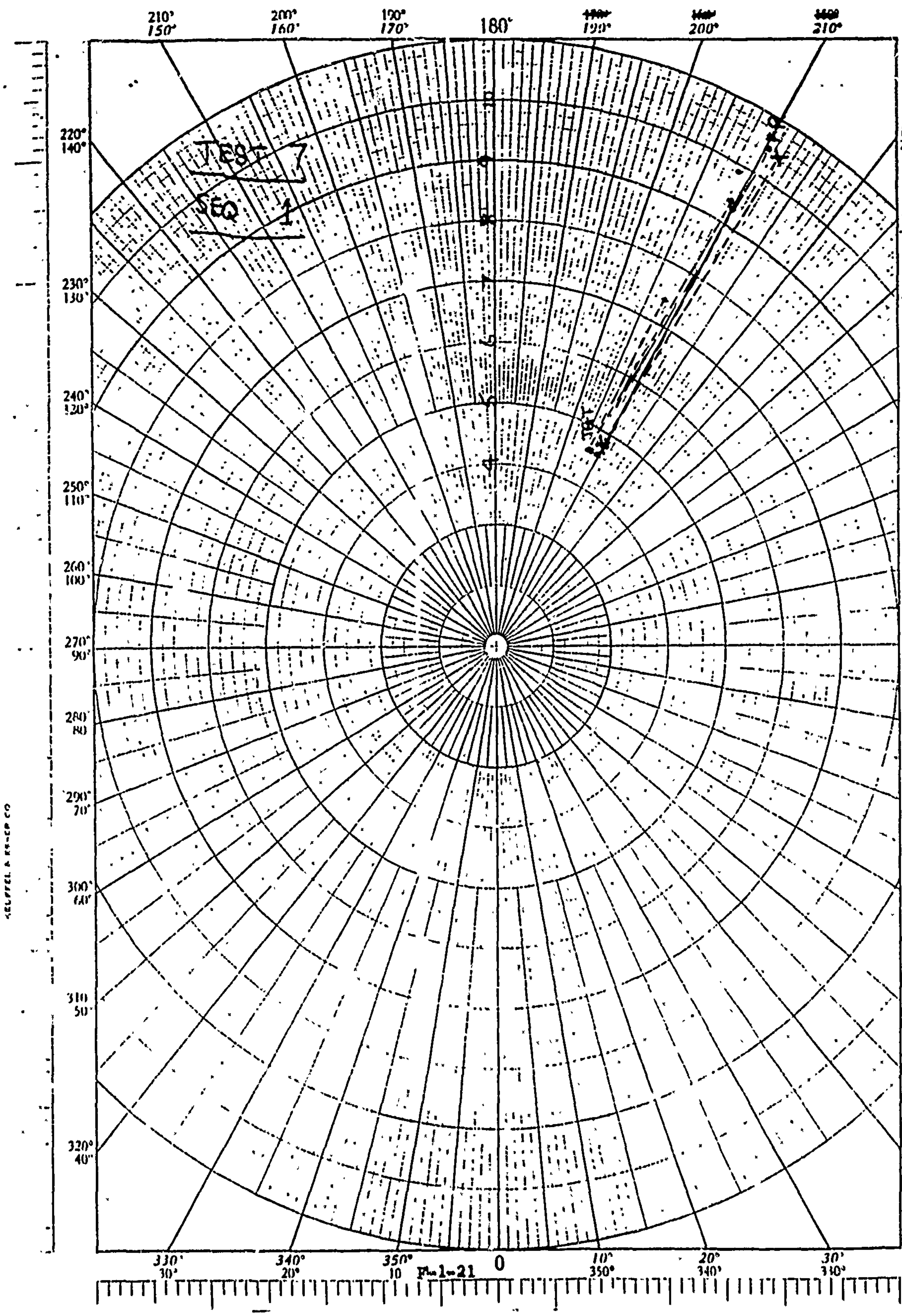


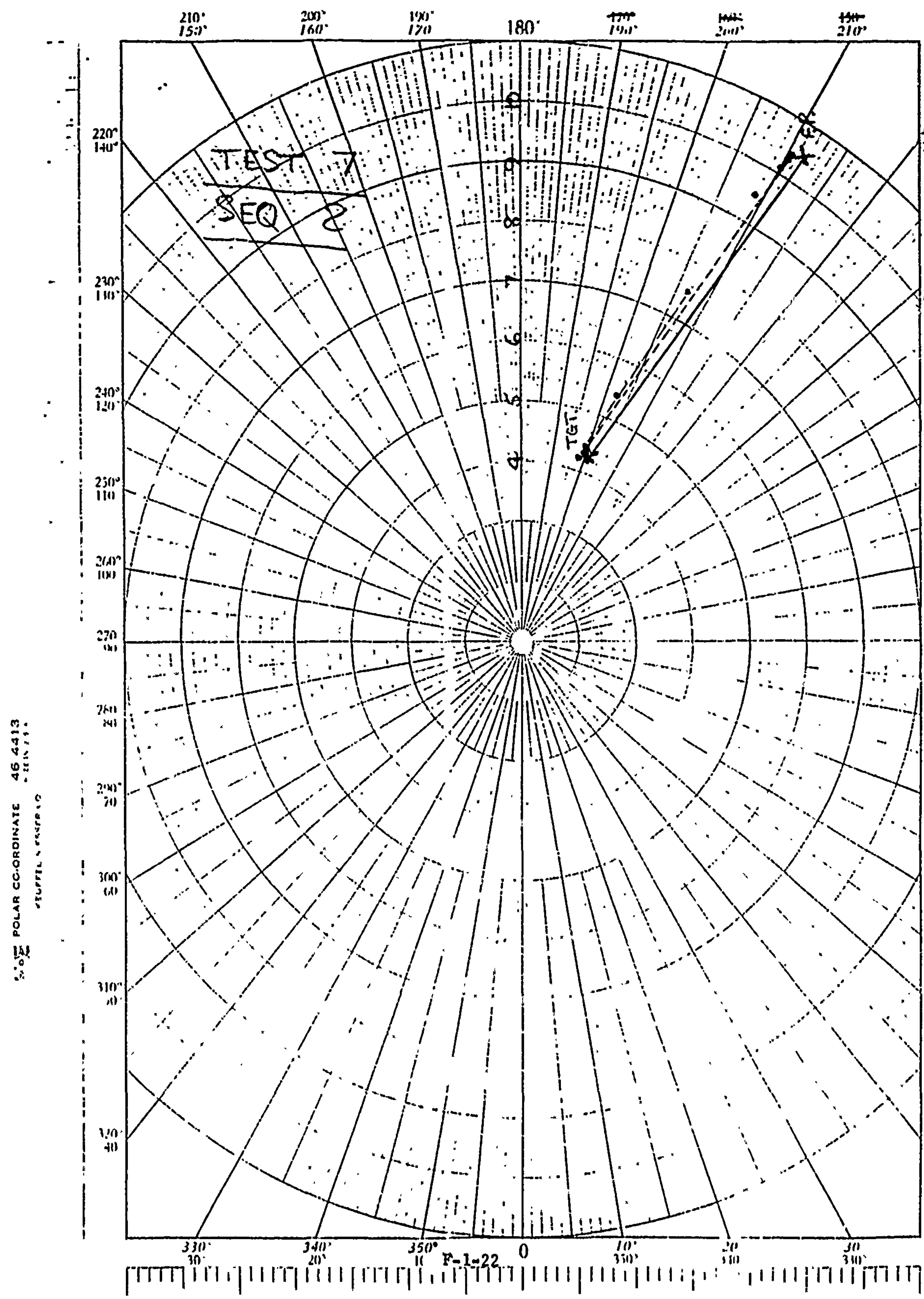


F-1-19

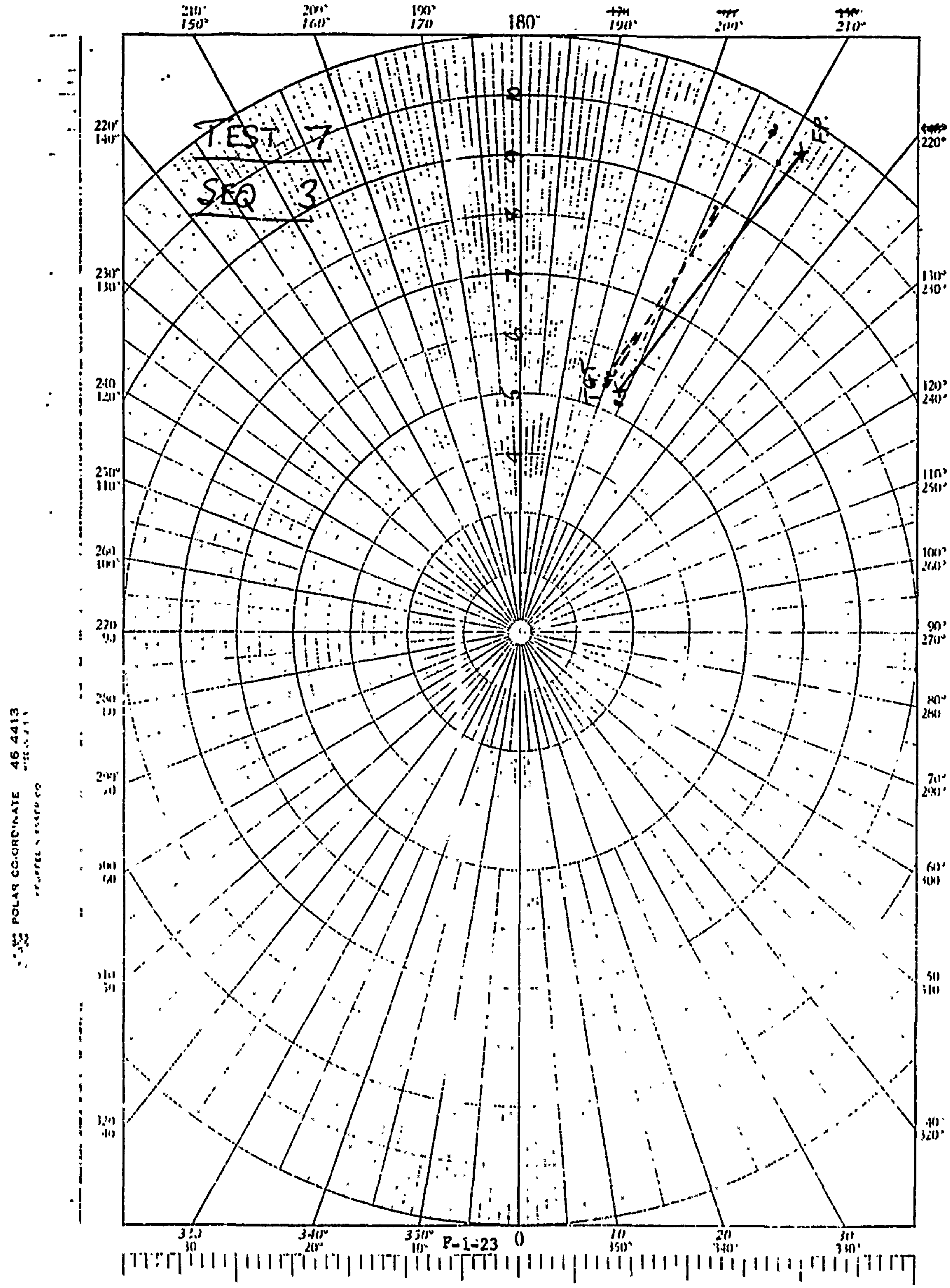


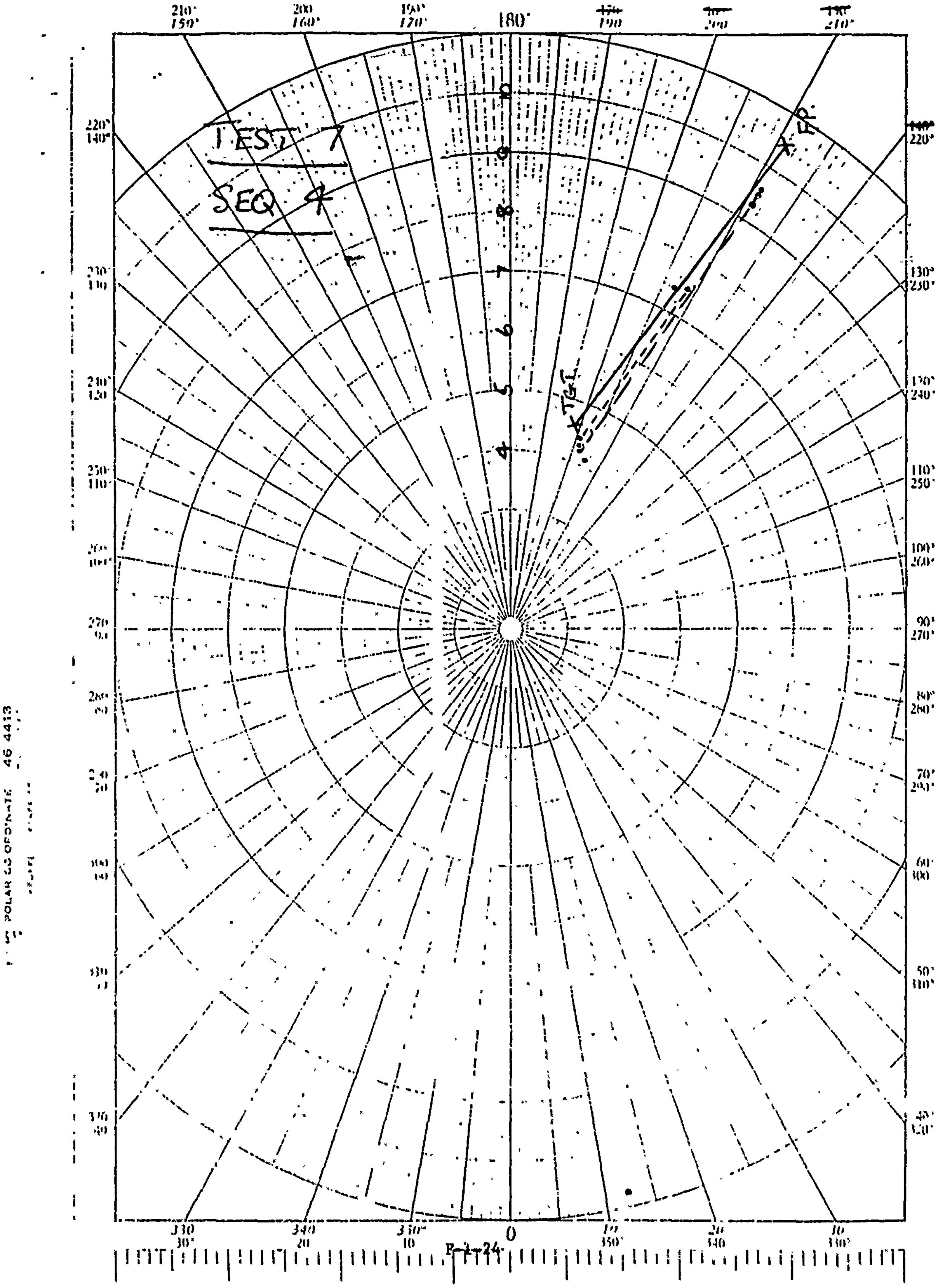
F-1-20

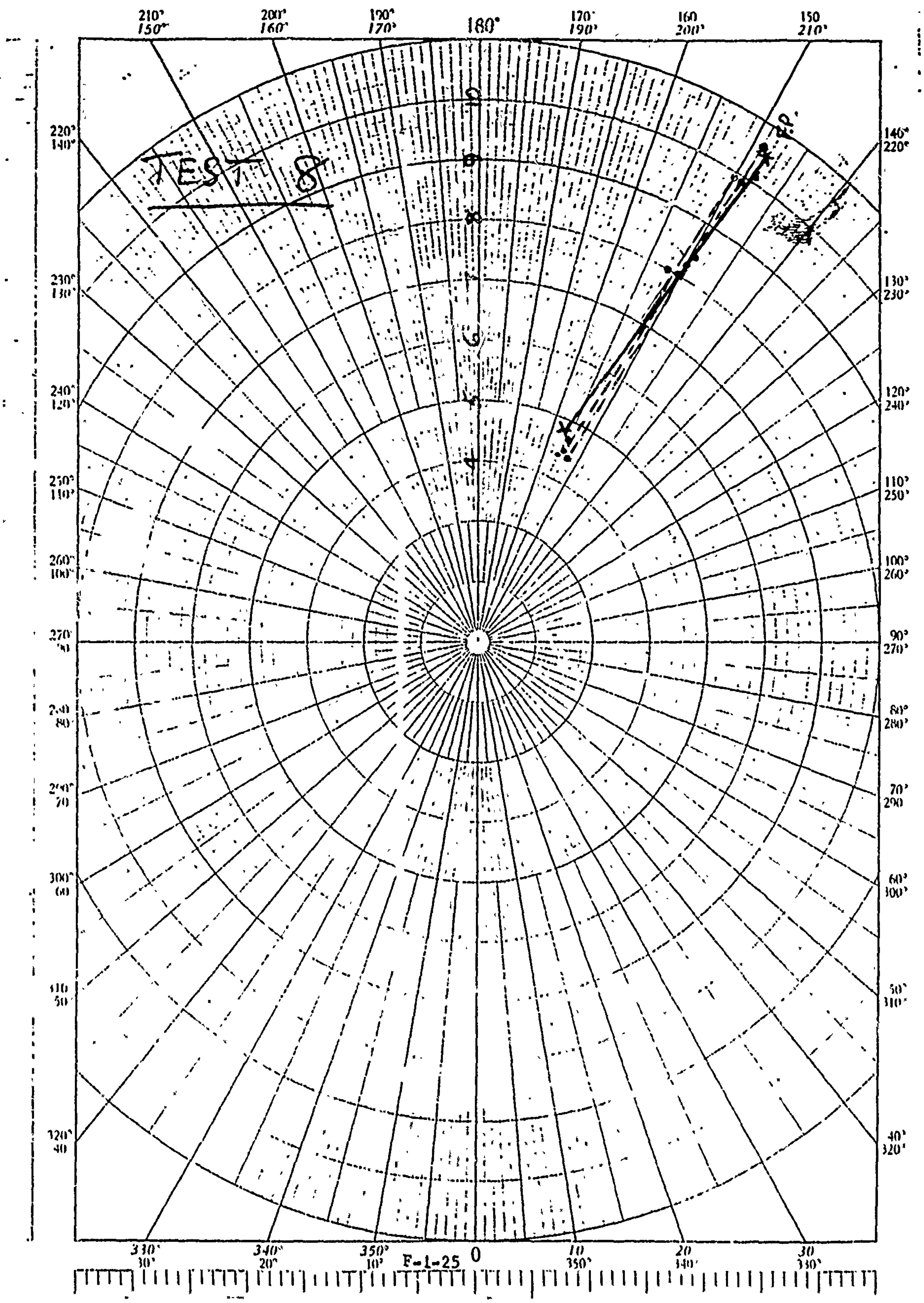

TEST 7
SEQ 1
180°
0
F-1-21

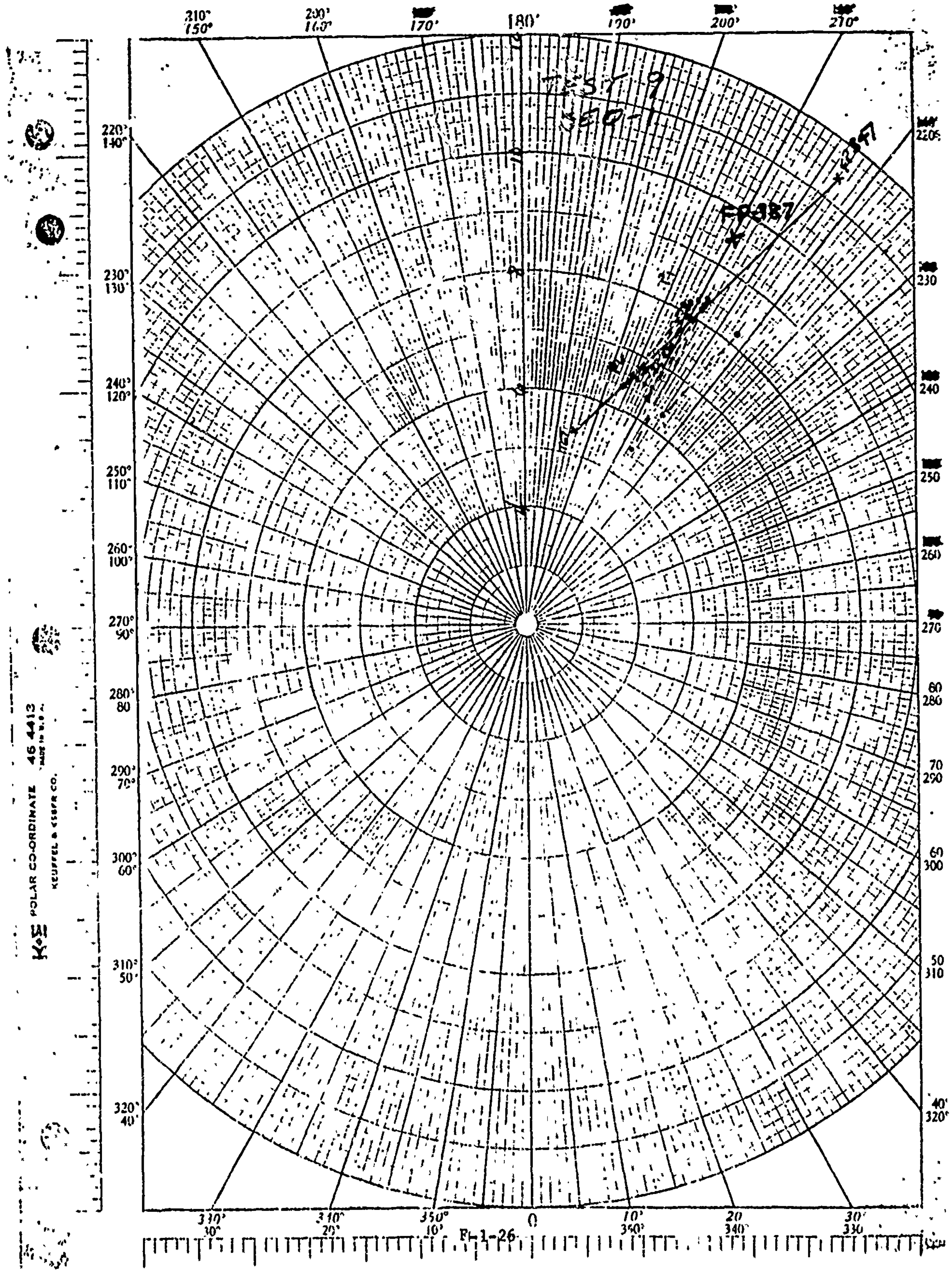


F-1-22


TEST 7
SEQ 3
180°
F-1-23
POLAR COORDINATE 46 4413


TEST 7
SEQ 4
TGT
FP
180°
0
4
5
6
7
8
9
10
POLAR COORDINATE 46 4413


TEST 8
180°
210° 150°
200° 160°
190° 170°
170° 190°
160 200°
150 210°
220° 140°
230° 130°
240° 120°
250° 110°
260° 100°
270° 90°
280° 80°
290° 70°
300° 60°
310 50°
320° 40°
140° 220°
130° 230°
120° 240°
110° 250°
100° 260°
90° 270°
80° 280°
70° 290°
60° 300°
50° 310°
40° 320°
330° 30°
340° 20°
350° 10°
0
10 350°
20 340°
30 330°
F-1-25
POLAR CO-ORDINATE 46 4413



K+E POLAR CO-ORDINATE 46 4413
KEUFFEL & ESSER CO.
180°
190°
200°
210°
170°
270°
90°
0
FR387
FL-1-26

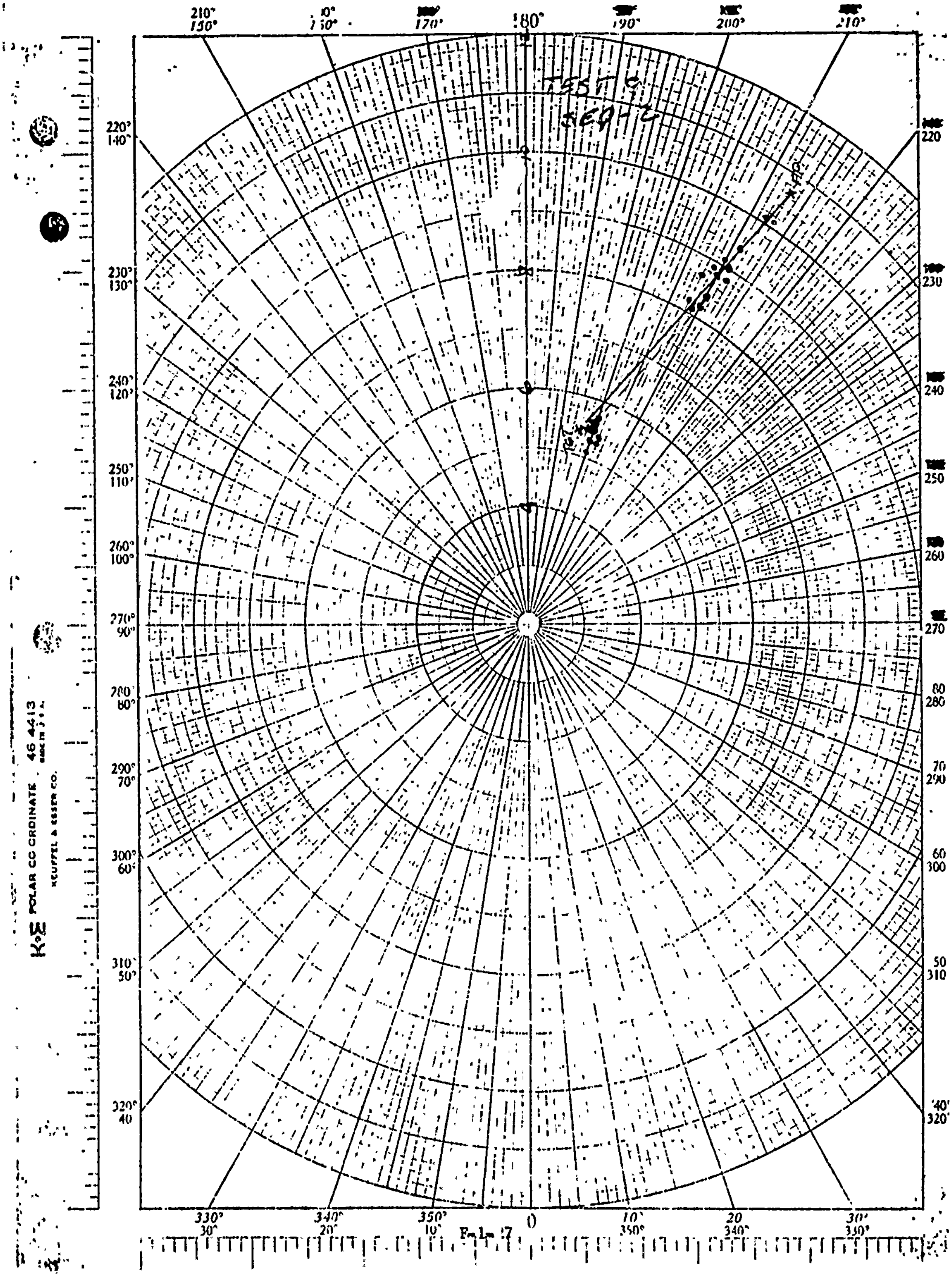
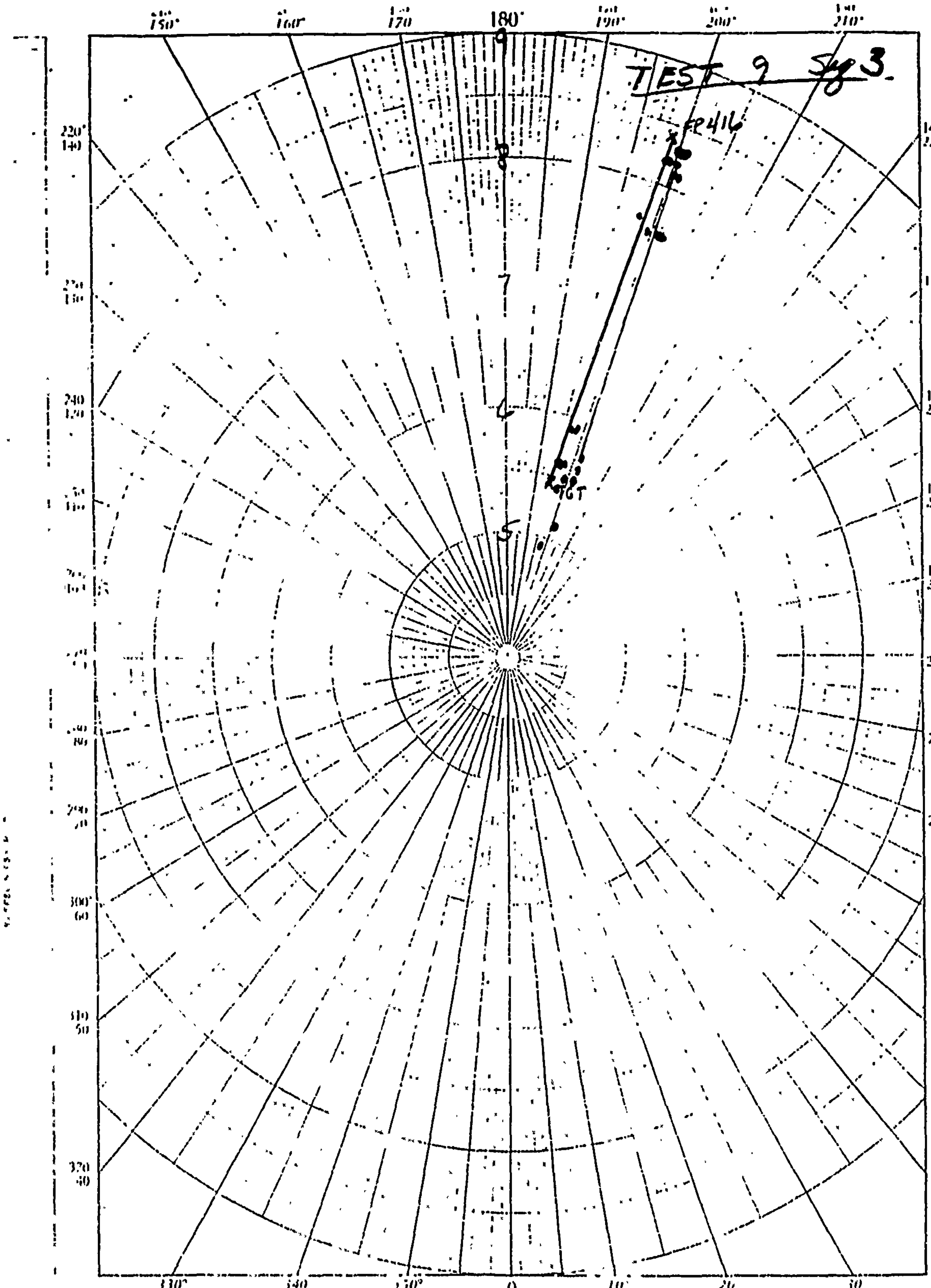
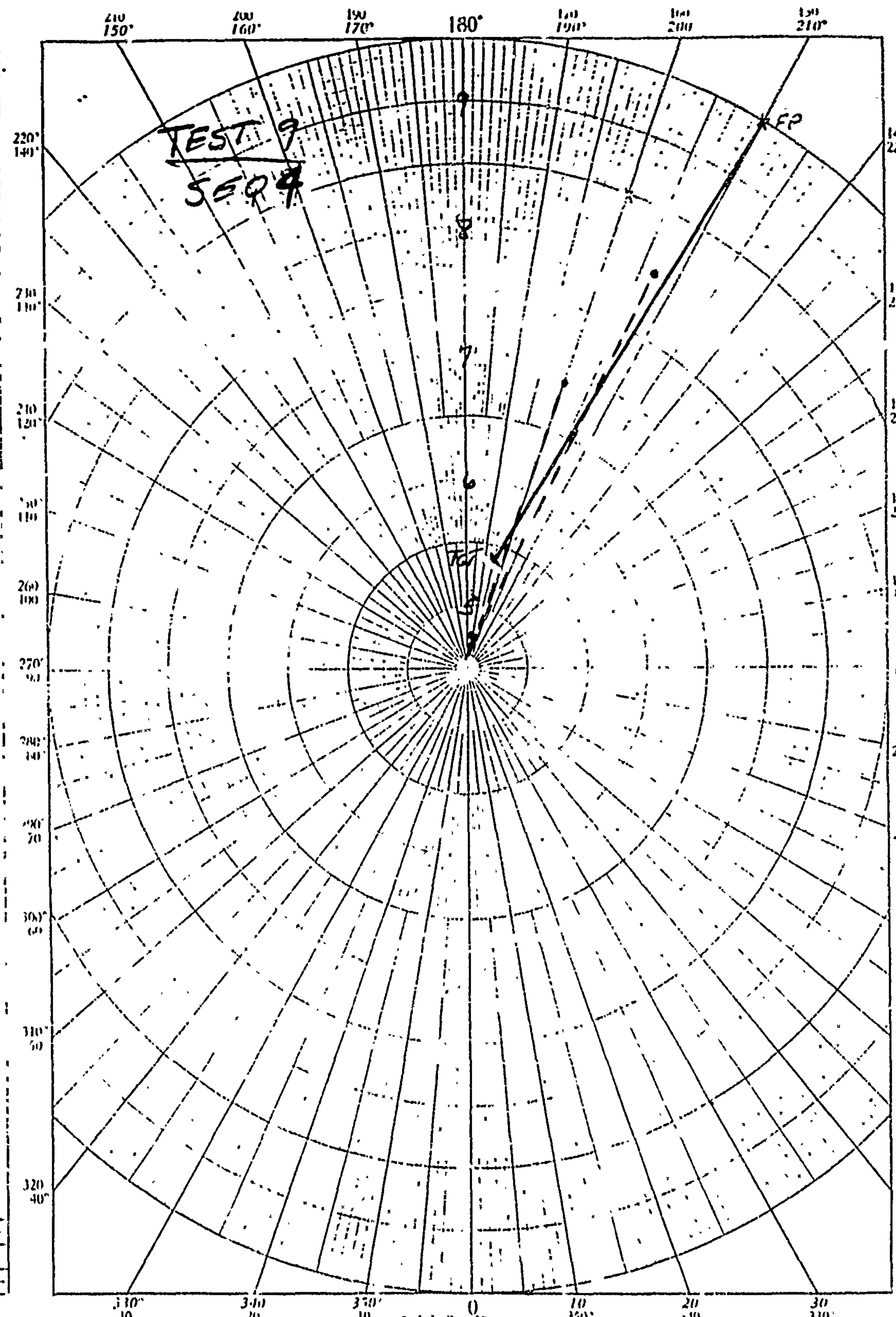
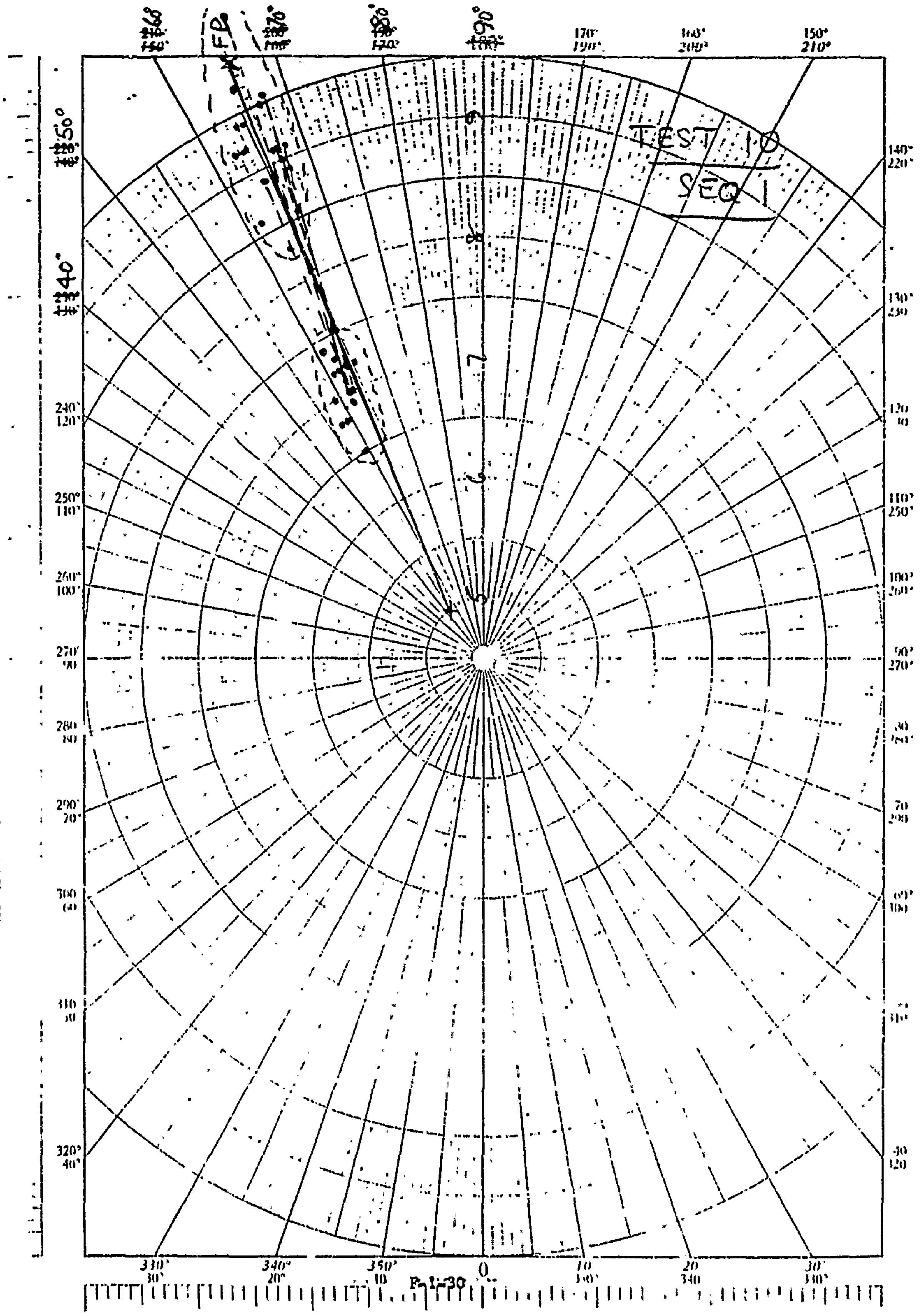


Fig. 17

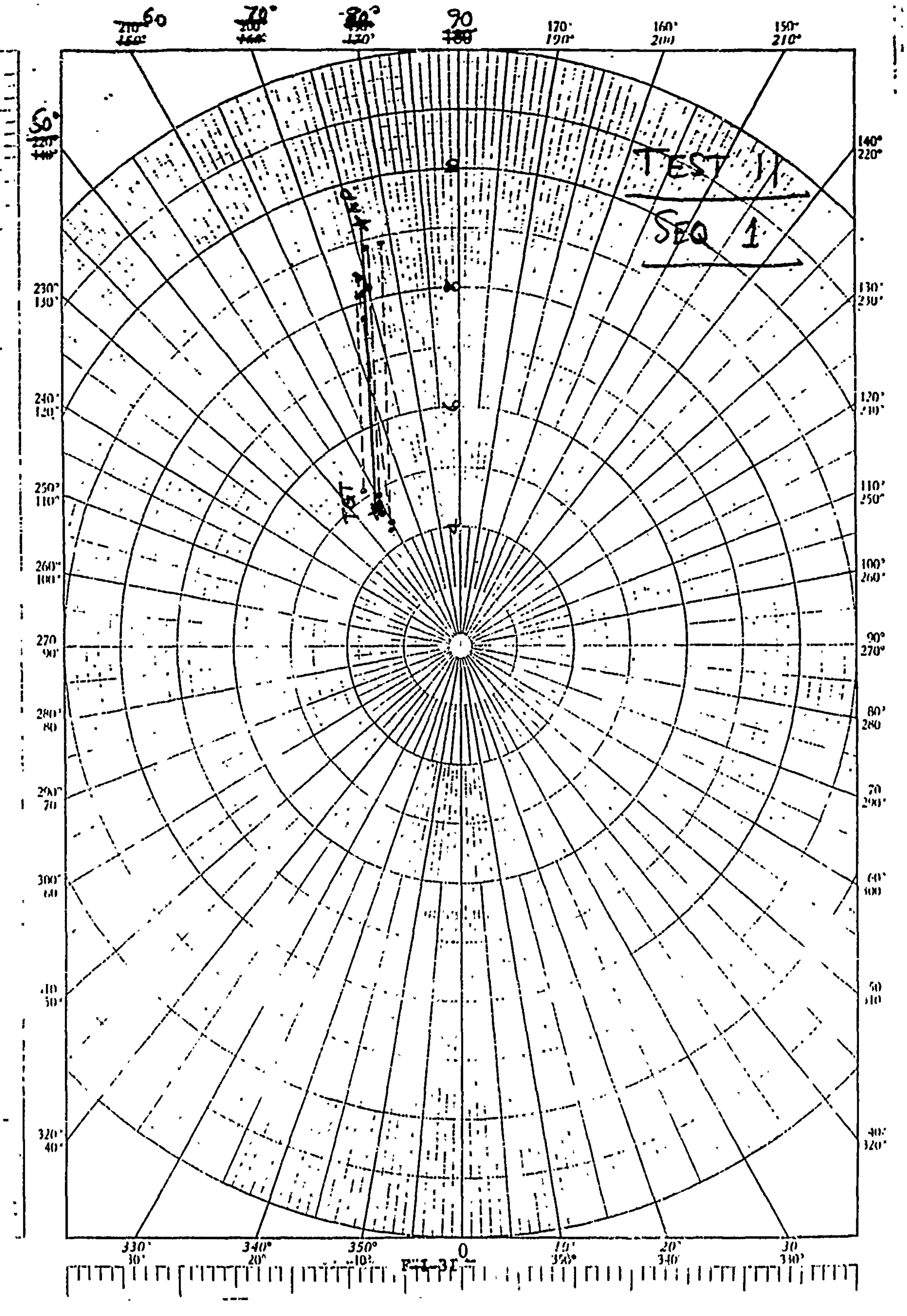

TEST 9 Sg 3.
FR416
TGT
180°
150°
160°
170°
190°
200°
210°
220°
140°
240
120
0
10°
20
30
330°
340
350°
9
8
7
6
5

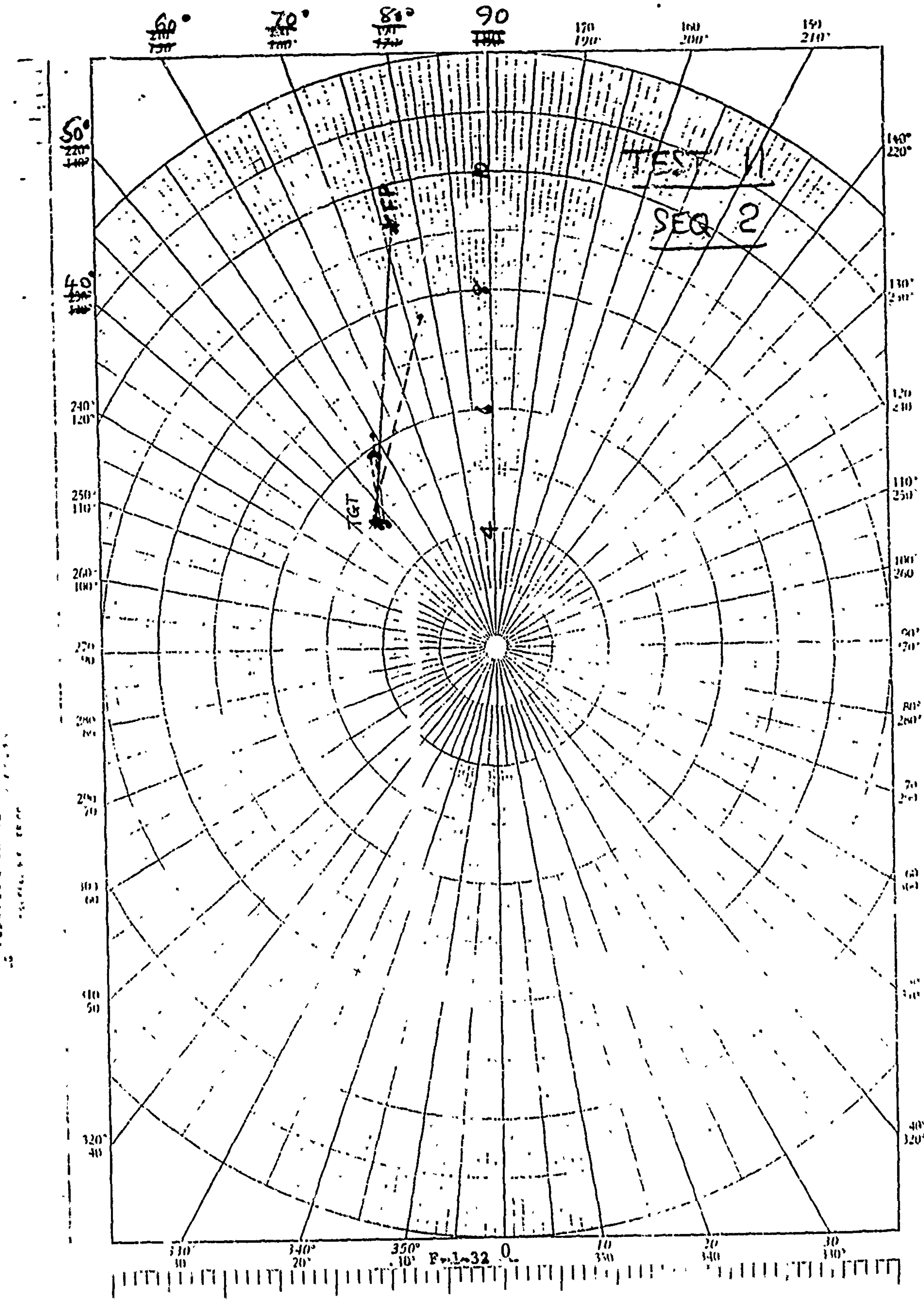


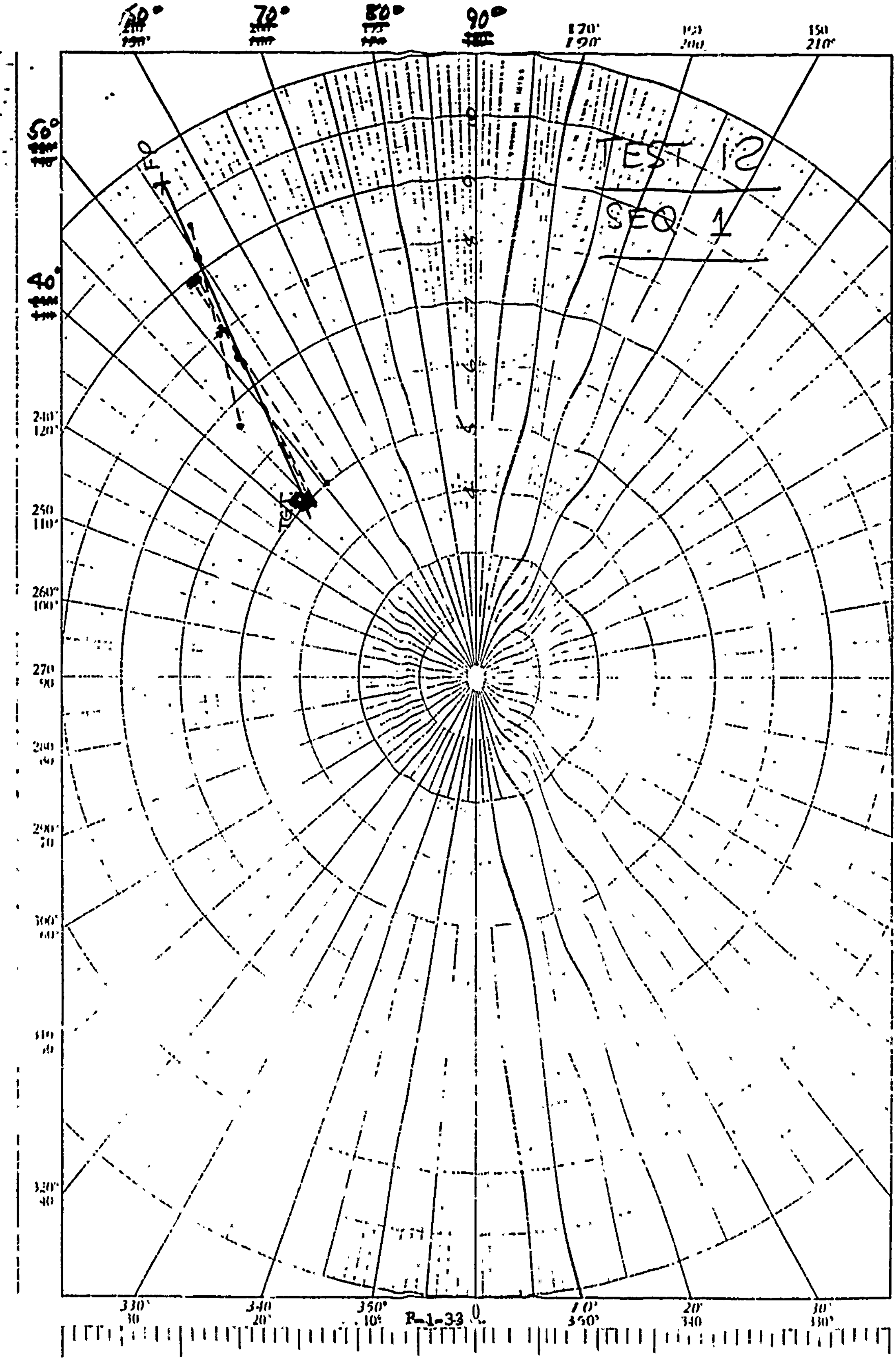
TEST 9
SEQ 4
FP
TG
180°

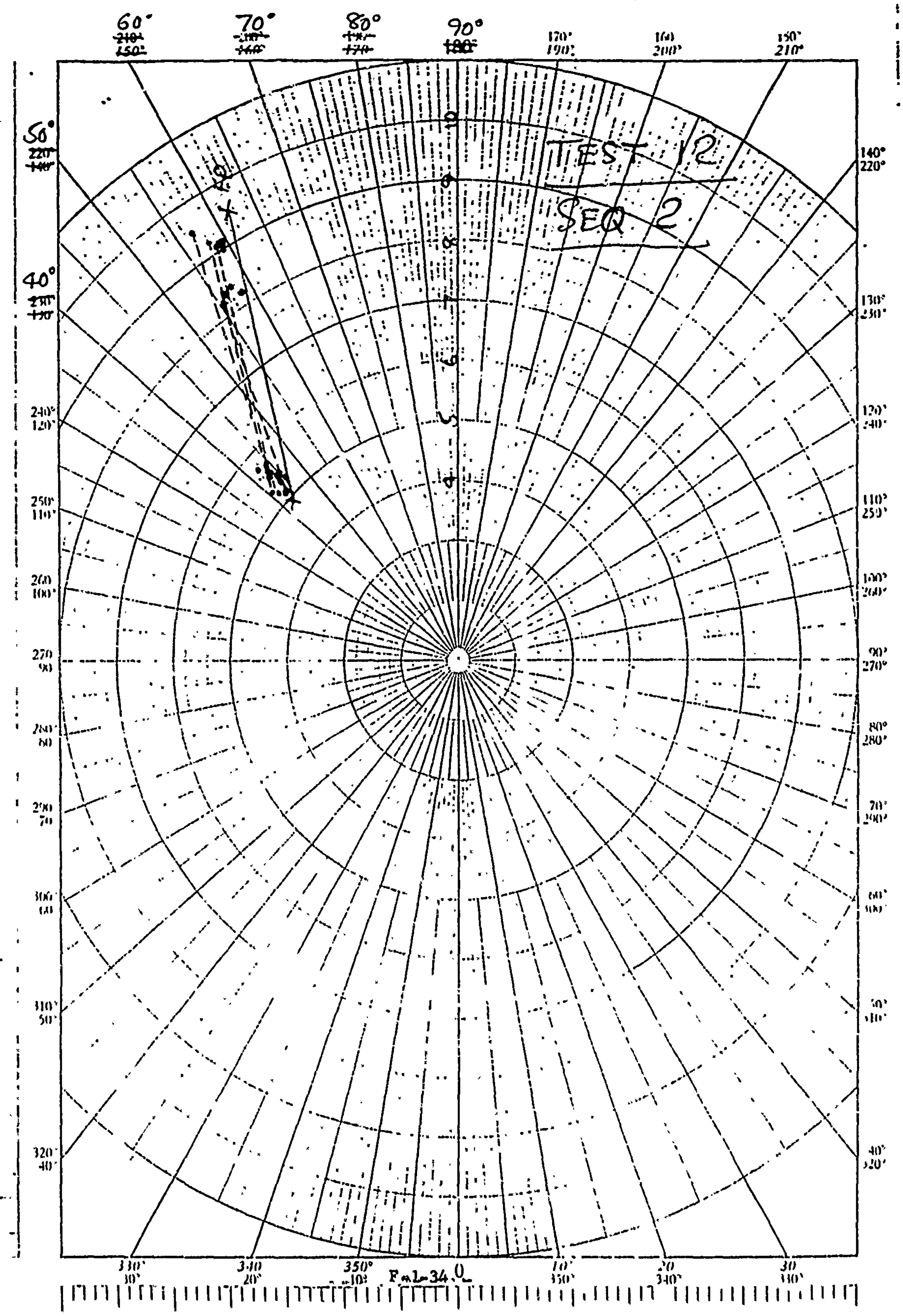


F-1-30

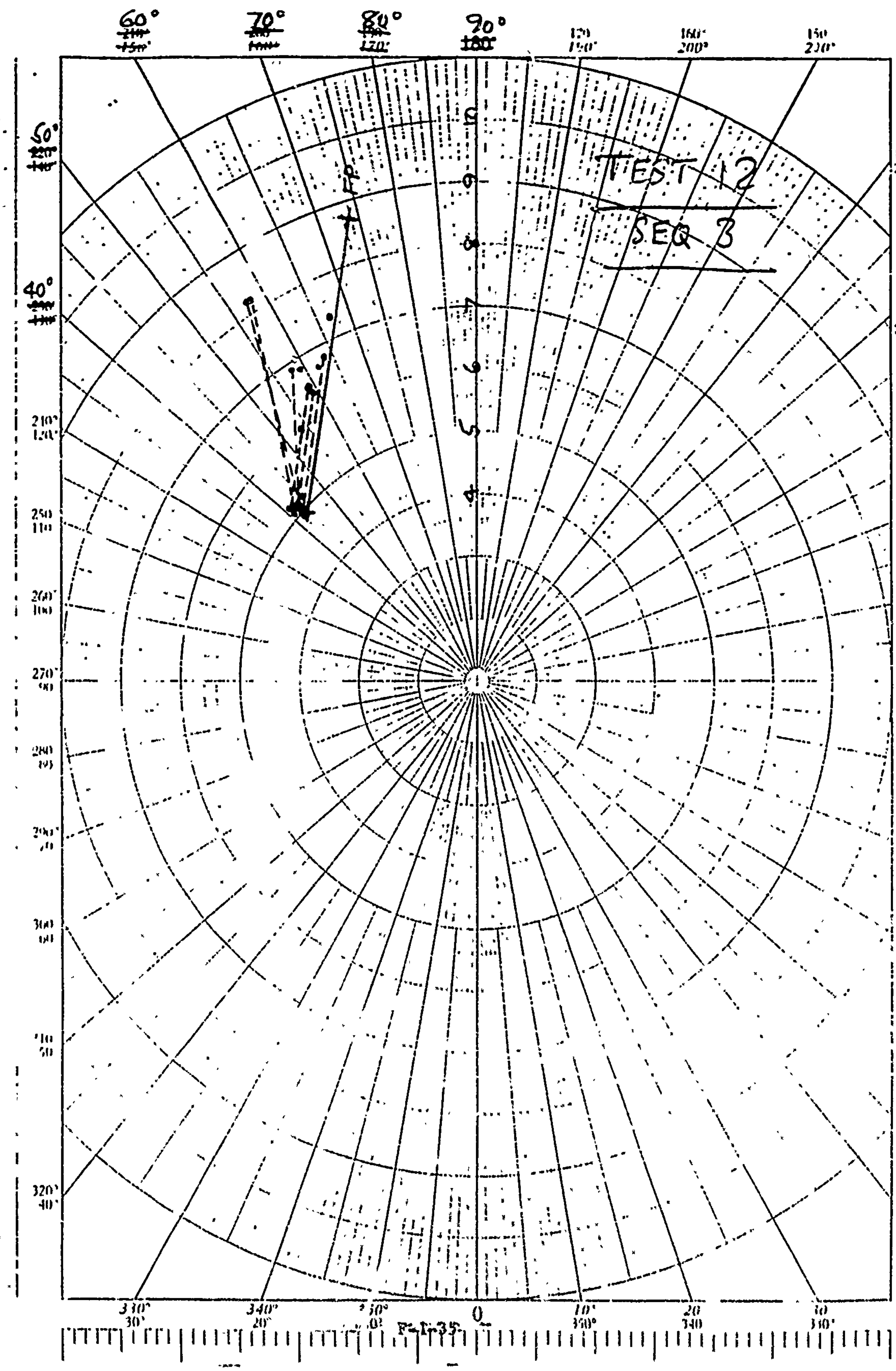

TEST 11
SEQ 1
60
70°
80°
90
170°
190°
160°
200
150°
210°
50°
140°
220°
230°
130°
240°
120°
250°
110°
260°
100°
270
90°
280°
80
290°
70
300°
60
310
50°
320°
40°
330°
30°
340°
20°
350°
10°
0
10°
350°
20°
340°
30
330°
F-1-31

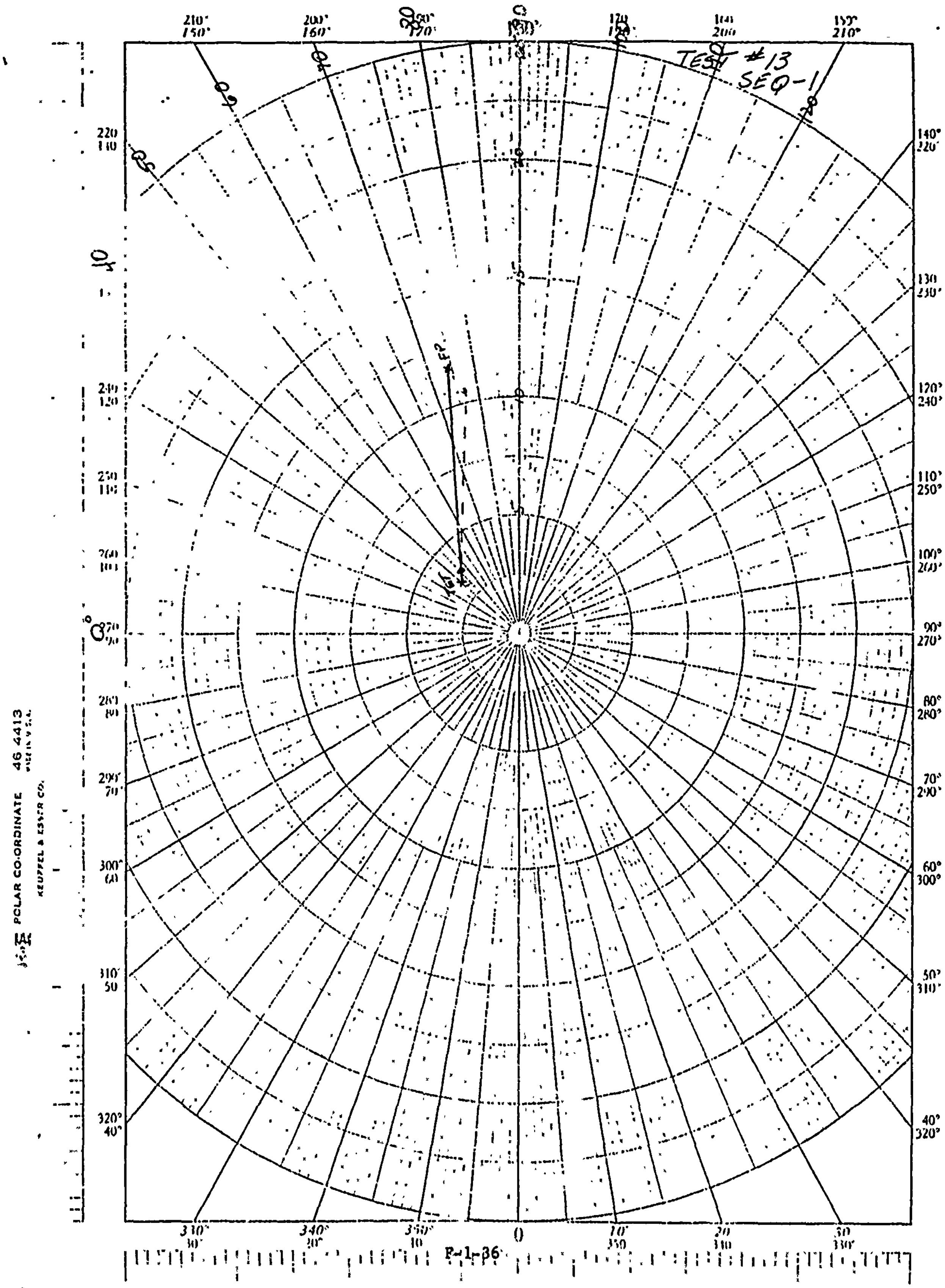

TEST 11
SEQ 2
60°
70°
80°
90
FP
TGT
F-1-32

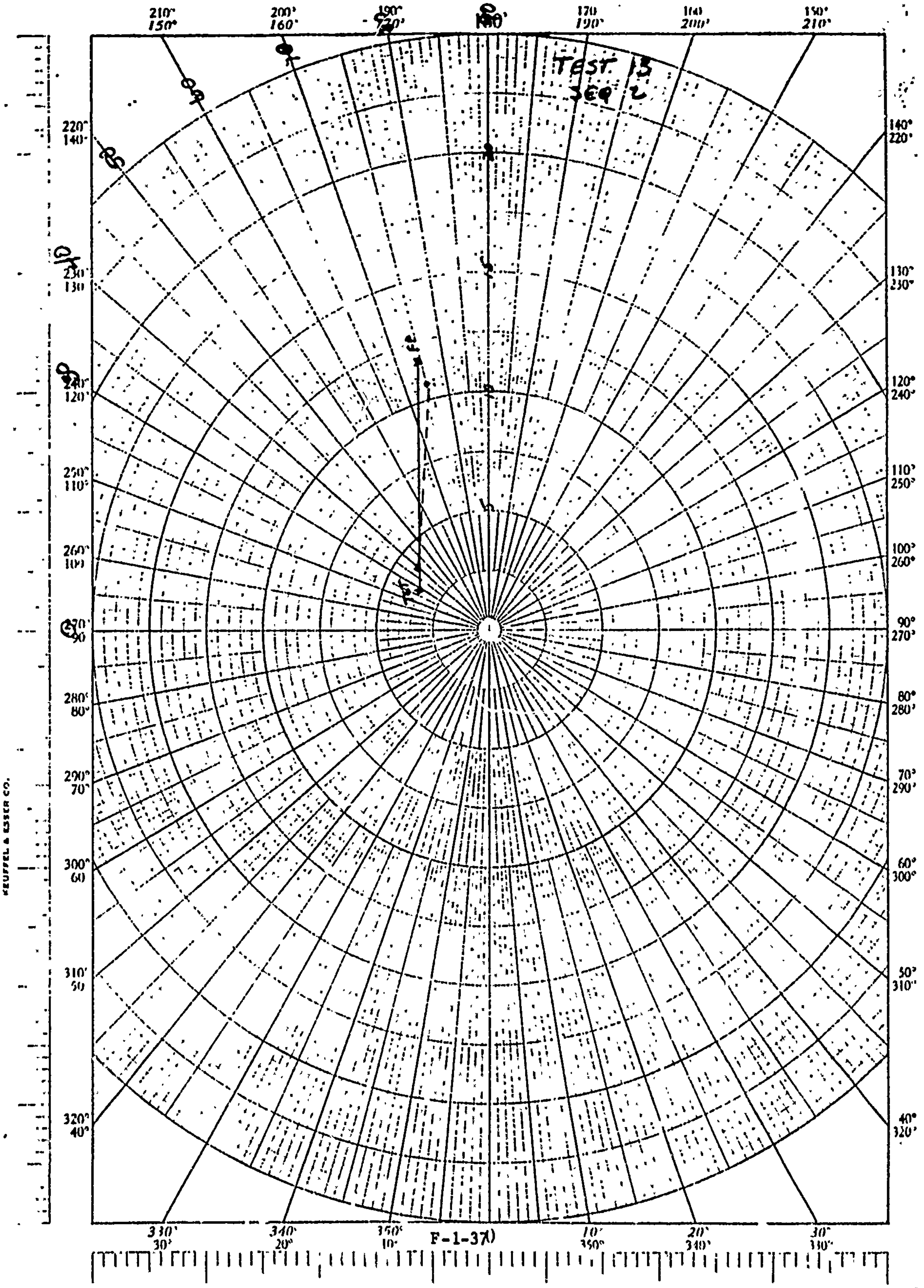

TEST 12
SEQ 1
60°
70°
80°
90°
170°
190°
210°
140°
220°
50°
40°
240°
120°
250°
110°
260°
100°
270
90
320°
40
330°
30
340
20°
350°
10°
0
10°
350°
20°
340
30°
330°
R-1-33

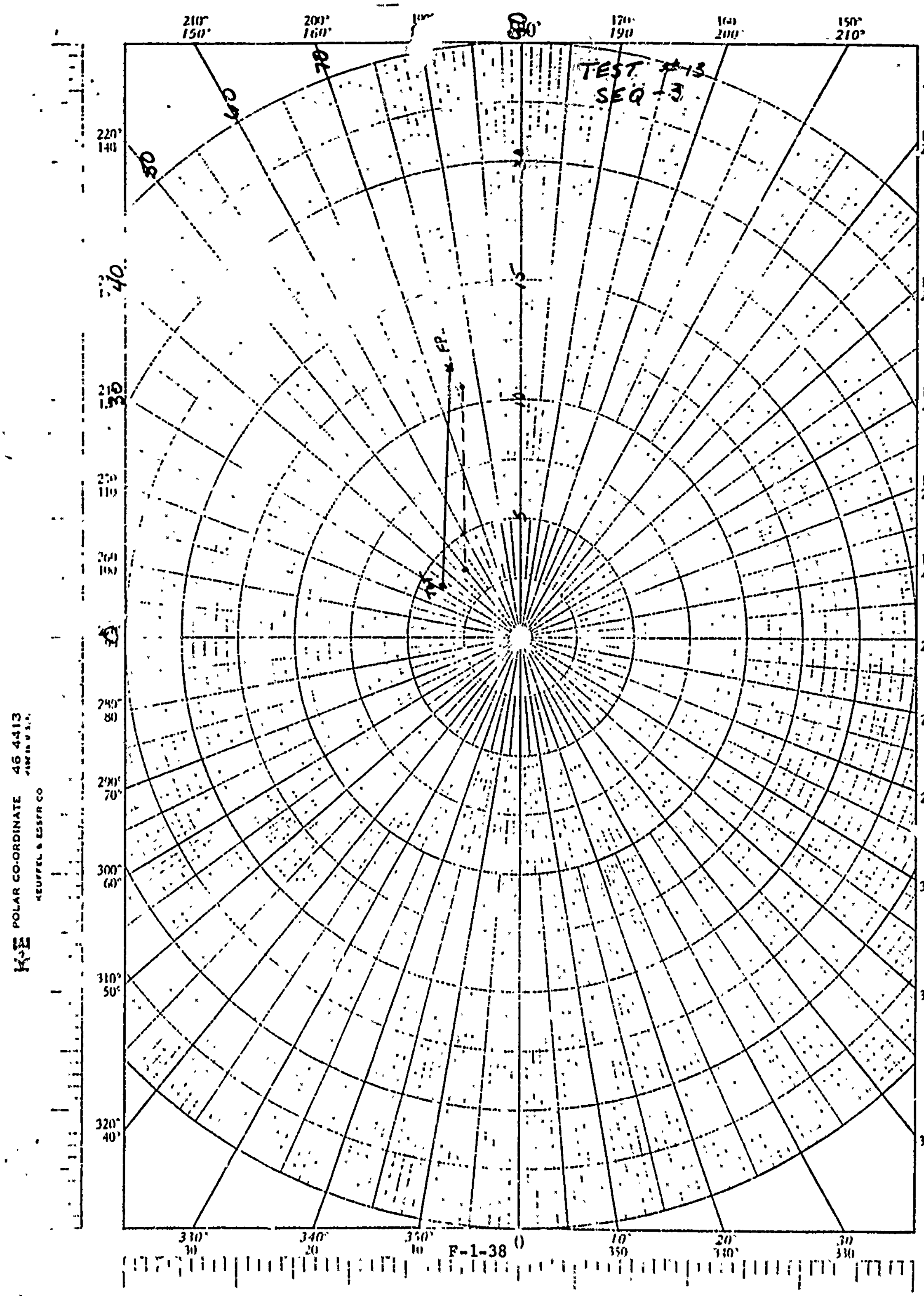

60°
70°
80°
90°
170°
190°
160
200°
150°
210°
50°
40°
140°
220°
130°
230°
120°
240°
110°
250°
100°
260°
90°
270°
80°
280°
70°
290°
60°
300°
50°
310°
40°
320°
240°
120°
250°
110°
260
100°
270
90
280
80
290
70
300
60
310°
50°
320°
40°
330°
30°
340
20°
350°
10°
0
10°
350°
20
340°
30
330°
TEST 12
SEQ 2
9
8
7
6
5
4

F-1-34.0

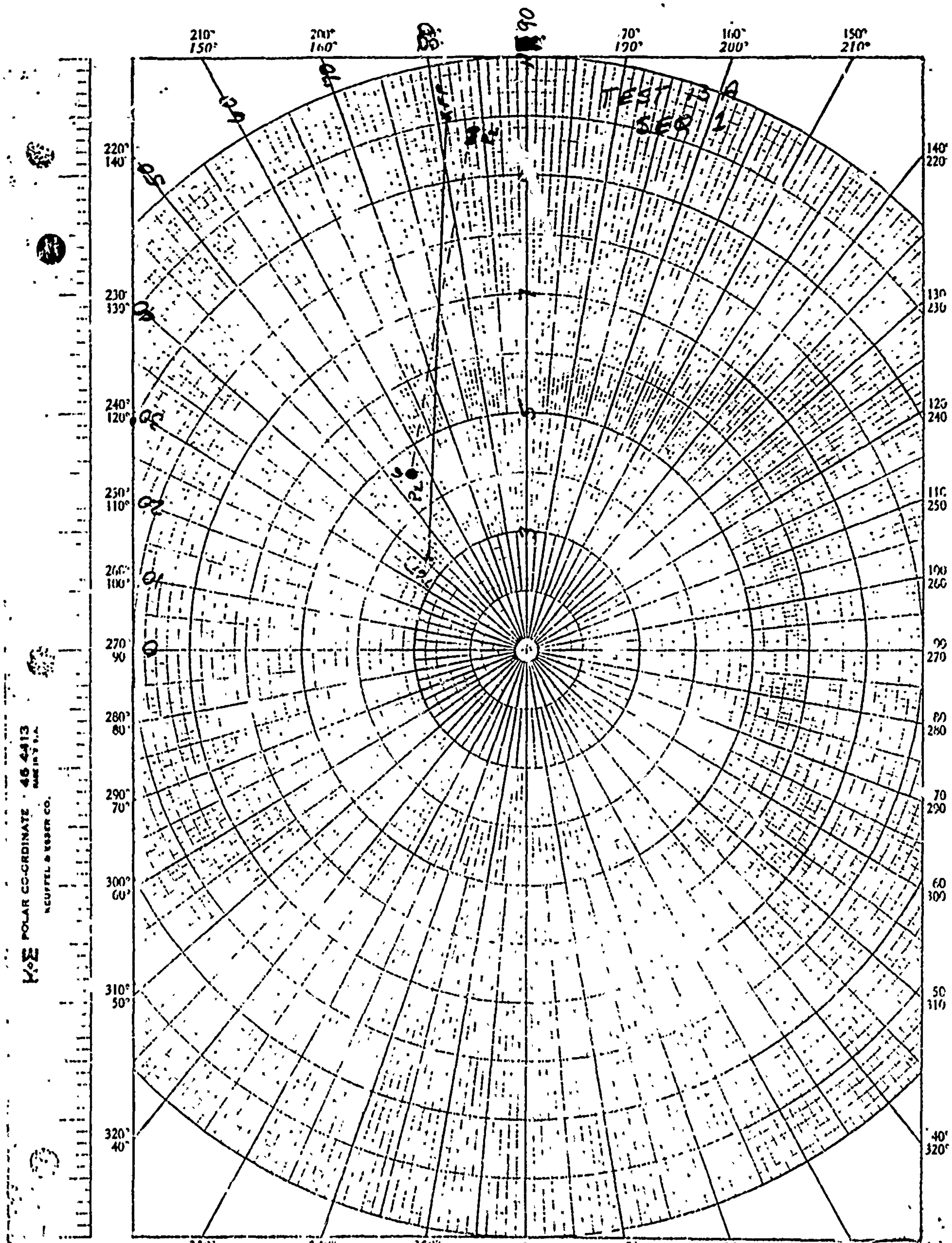

60°
70°
80°
90°
50°
40°
TEST 12
SEQ 3
330°
340°
0
10°
20
30
140°
220°
130°
230°
120
240
110°
250°
100°
260°
90°
270°
320°
40°


TEST #13
SEQ-1
F?
POLAR CO-ORDINATE 46 4413
KEUFFEL & ESSER CO.
F-1-36

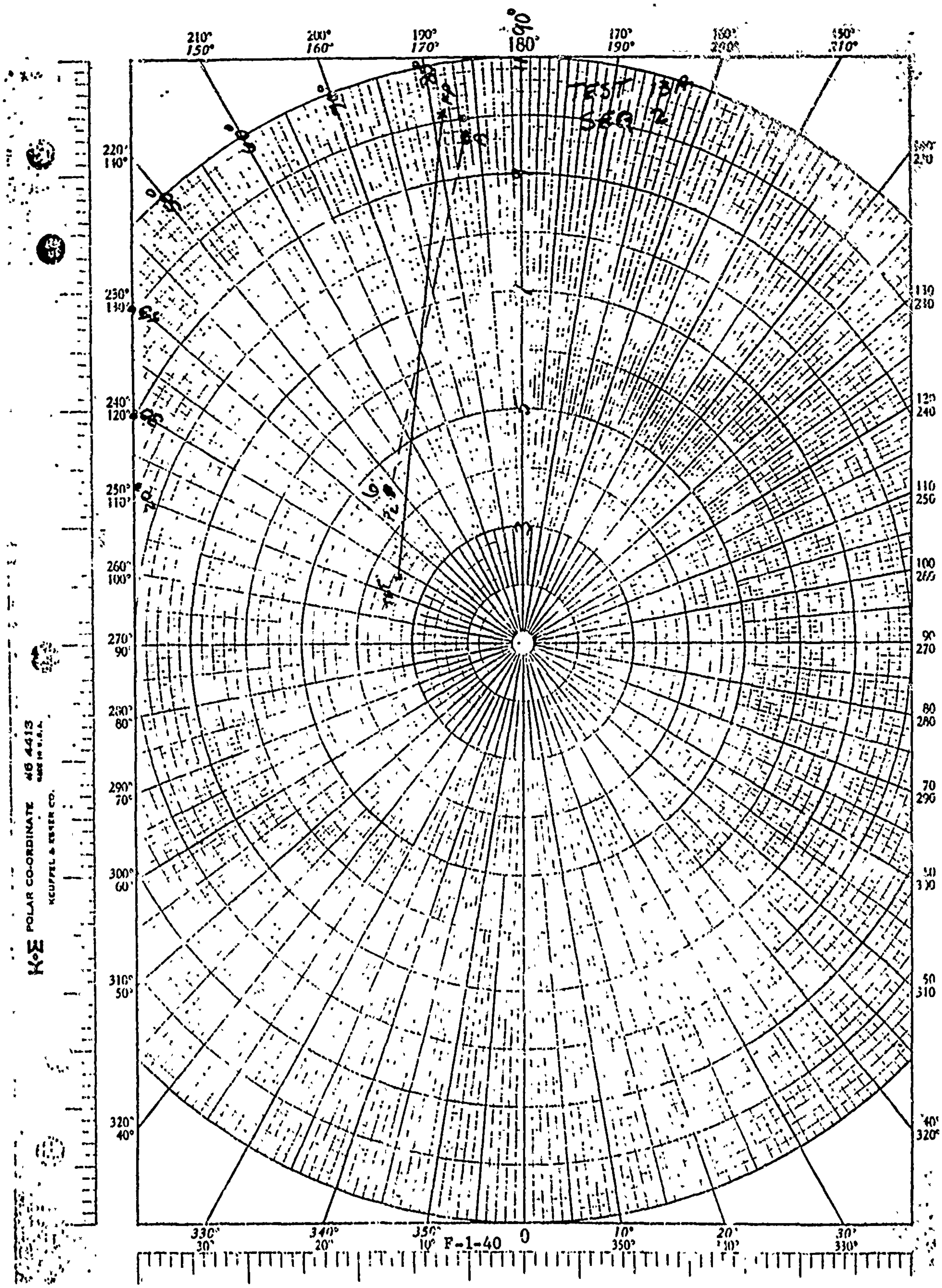

TEST 13
SEQ 2
F-1-370
POLAR CO-ORDINATE 46 4413
KEUFFEL & ESSER CO.

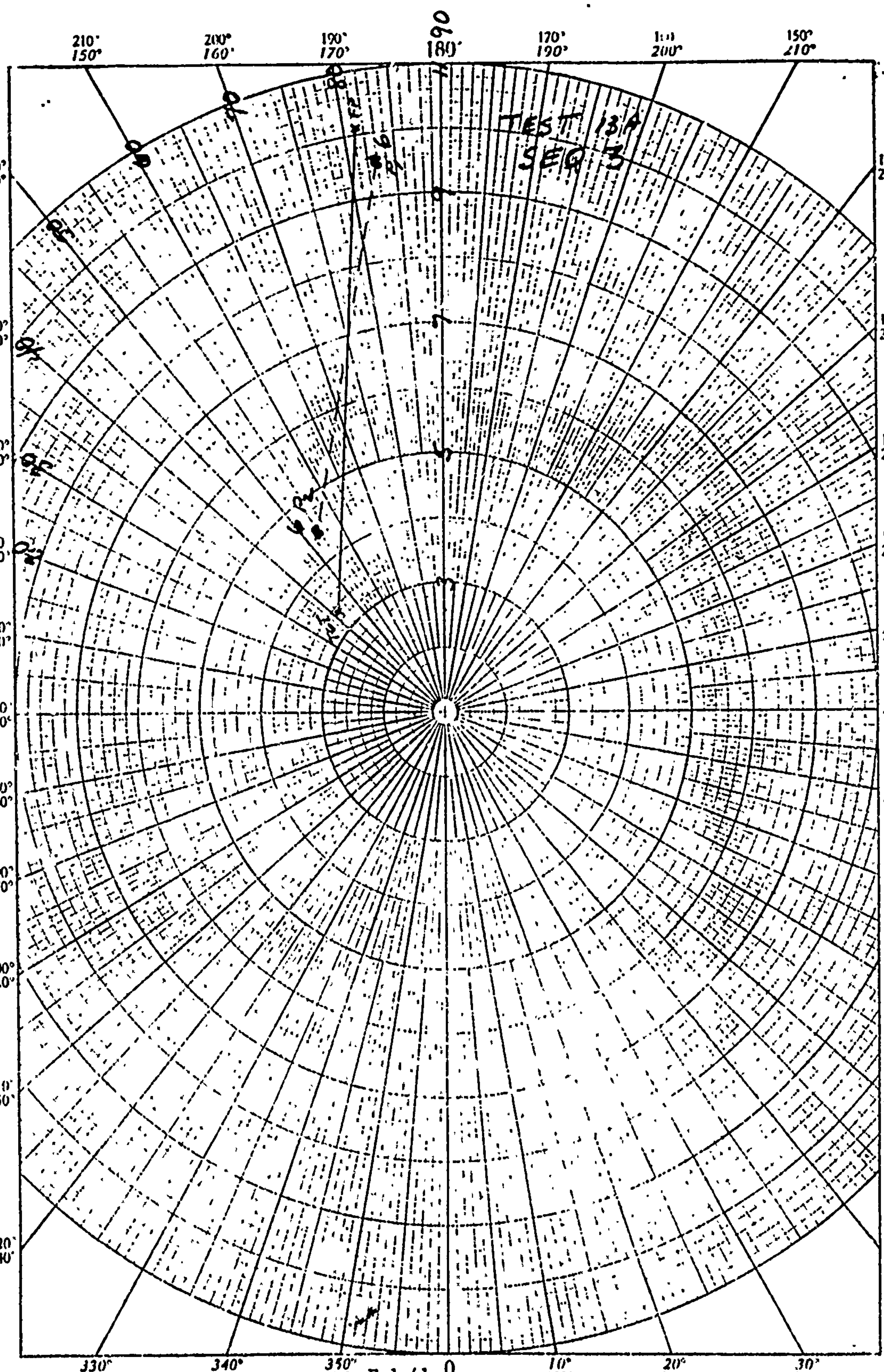


F-1-38

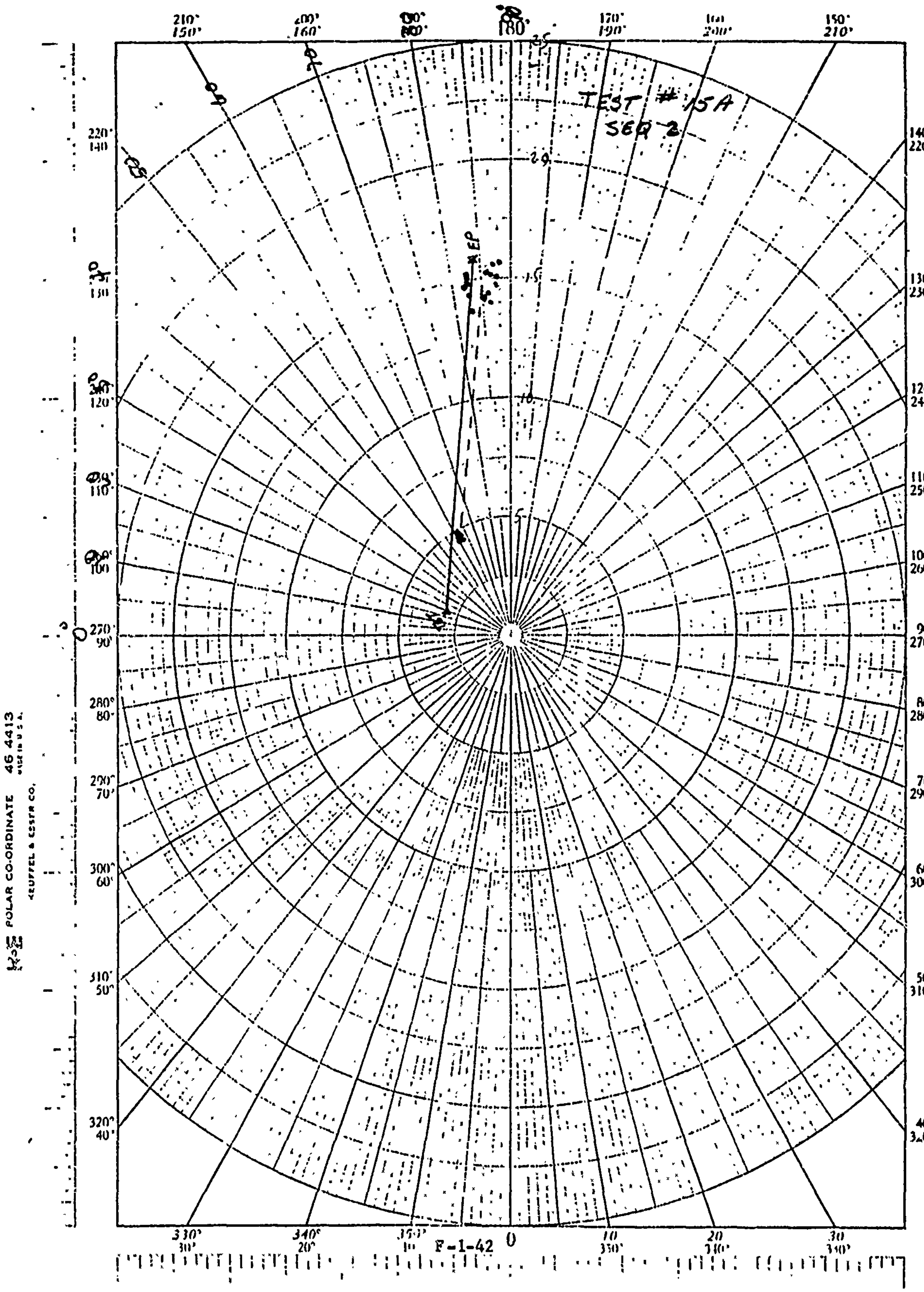


F-1-39

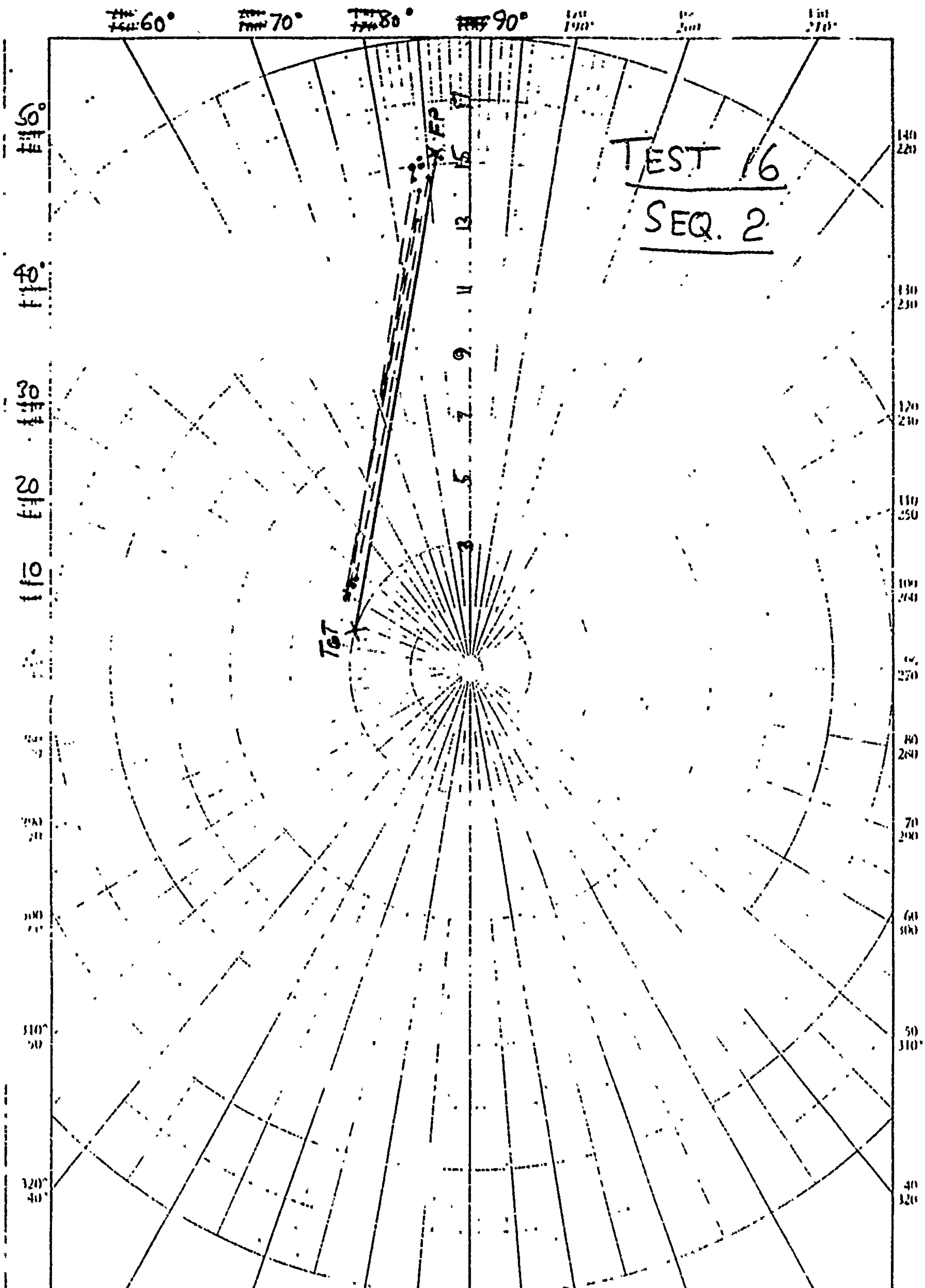

TEST 13A
SEQ 2
K+E POLAR CO-ORDINATE 46 4413
KEUFFEL & ESSER CO.
F-1-40

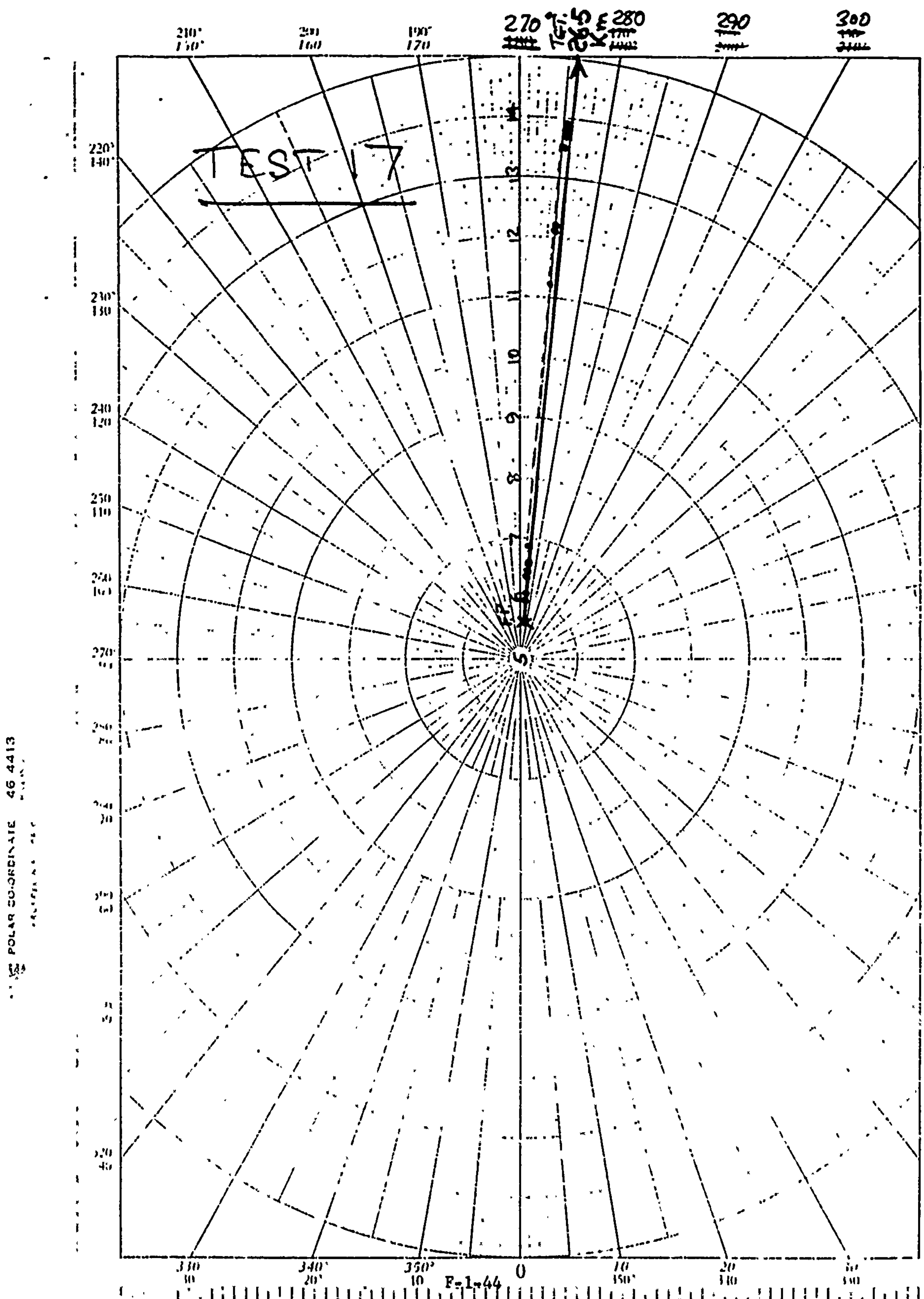


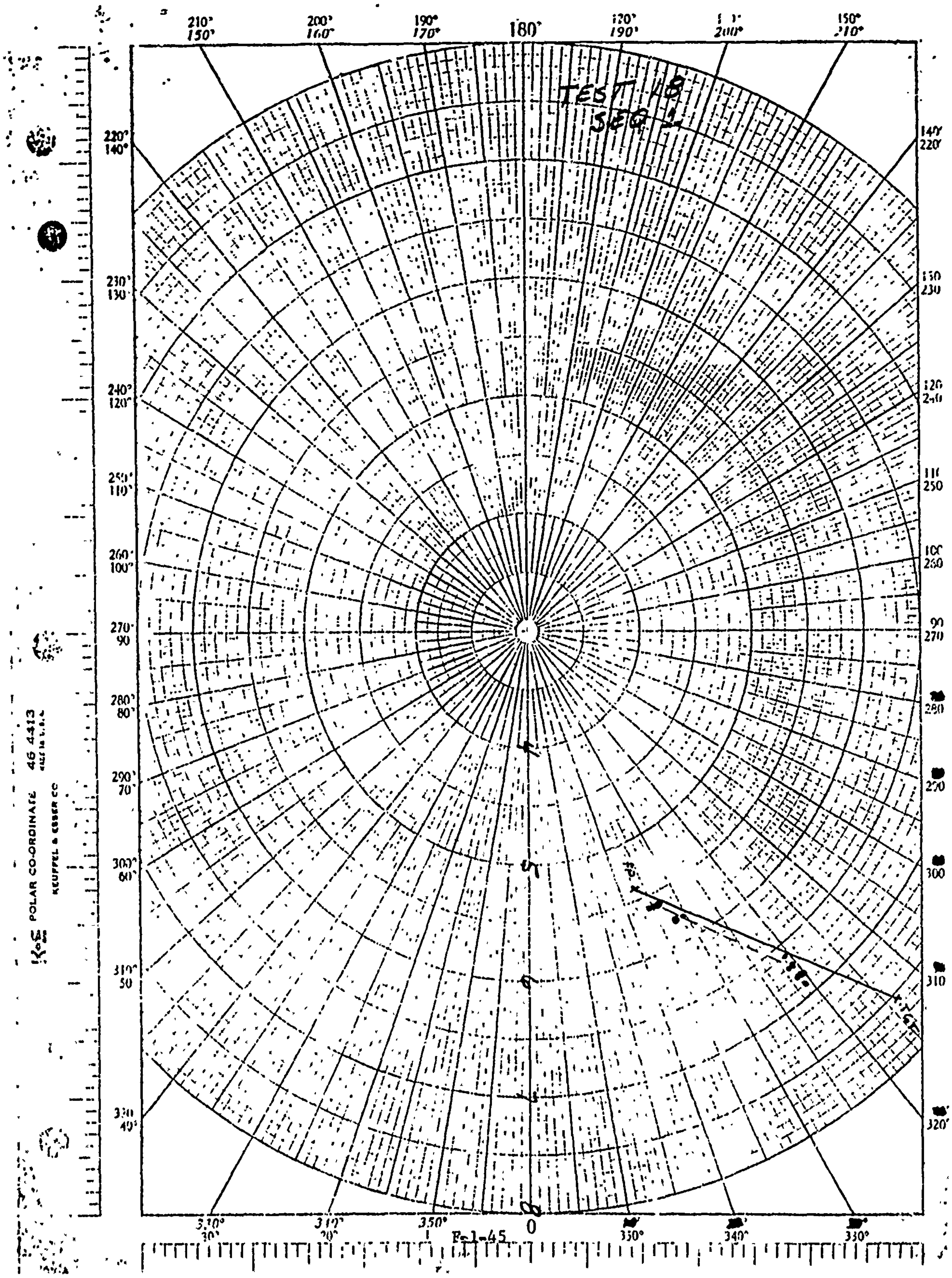
K&E POLAR CO-ORDINATE 46 4413
KEUFFEL & ESSER CO.

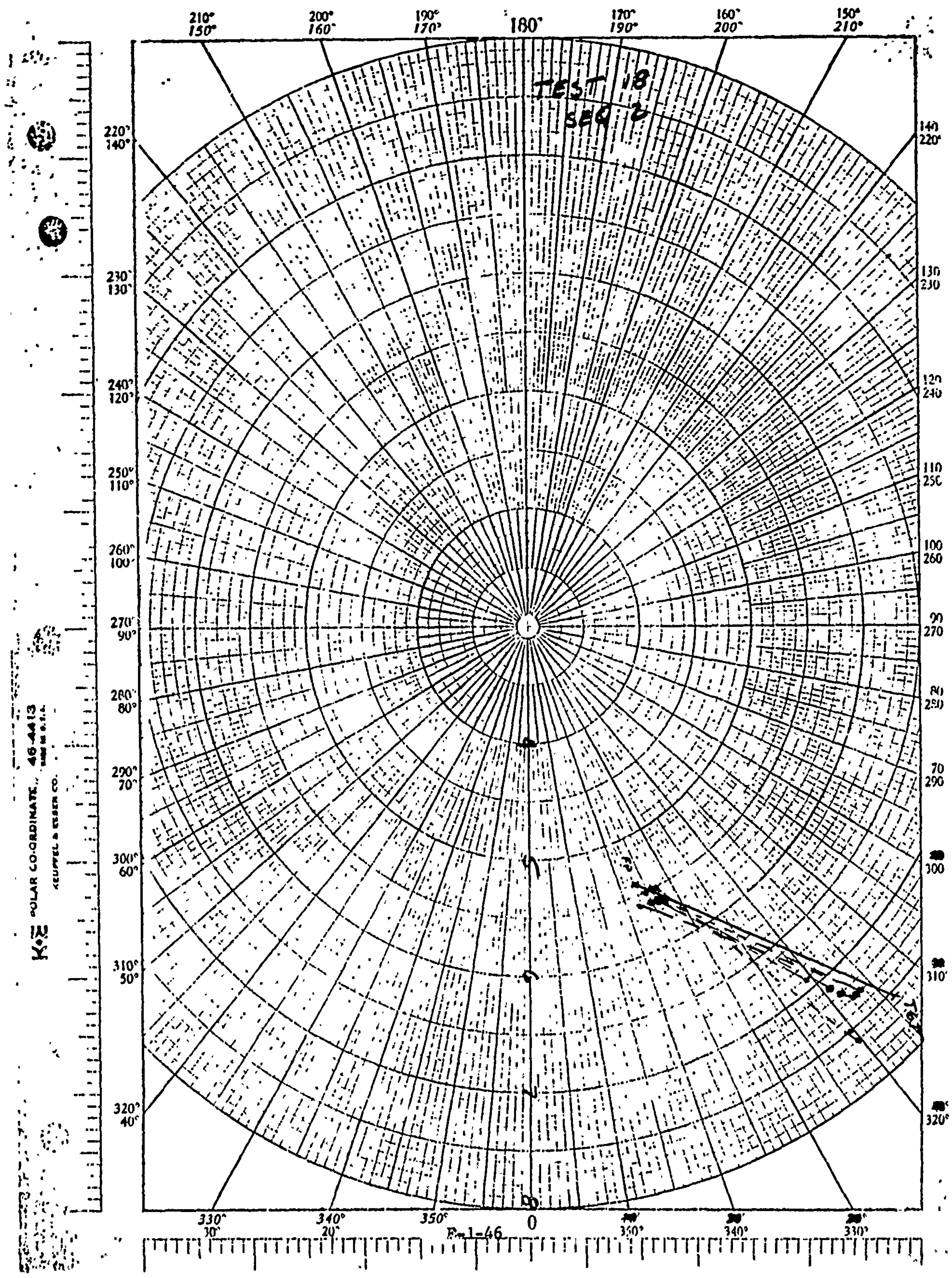

TEST #15A
SEQ 2
EP
POLAR CO-ORDINATE 46 4413
KEUFFEL & ESSER CO.
180°
170° 190°
150° 210°
210° 150°
140° 220°
220° 140°
130° 230°
120° 240°
110° 250°
100° 260°
90° 270°
270° 90°
80° 280°
280° 80°
70° 290°
290° 70°
60° 300°
300° 60°
50° 310°
310° 50°
40° 320°
320° 40°
330° 30°
340° 20°
0

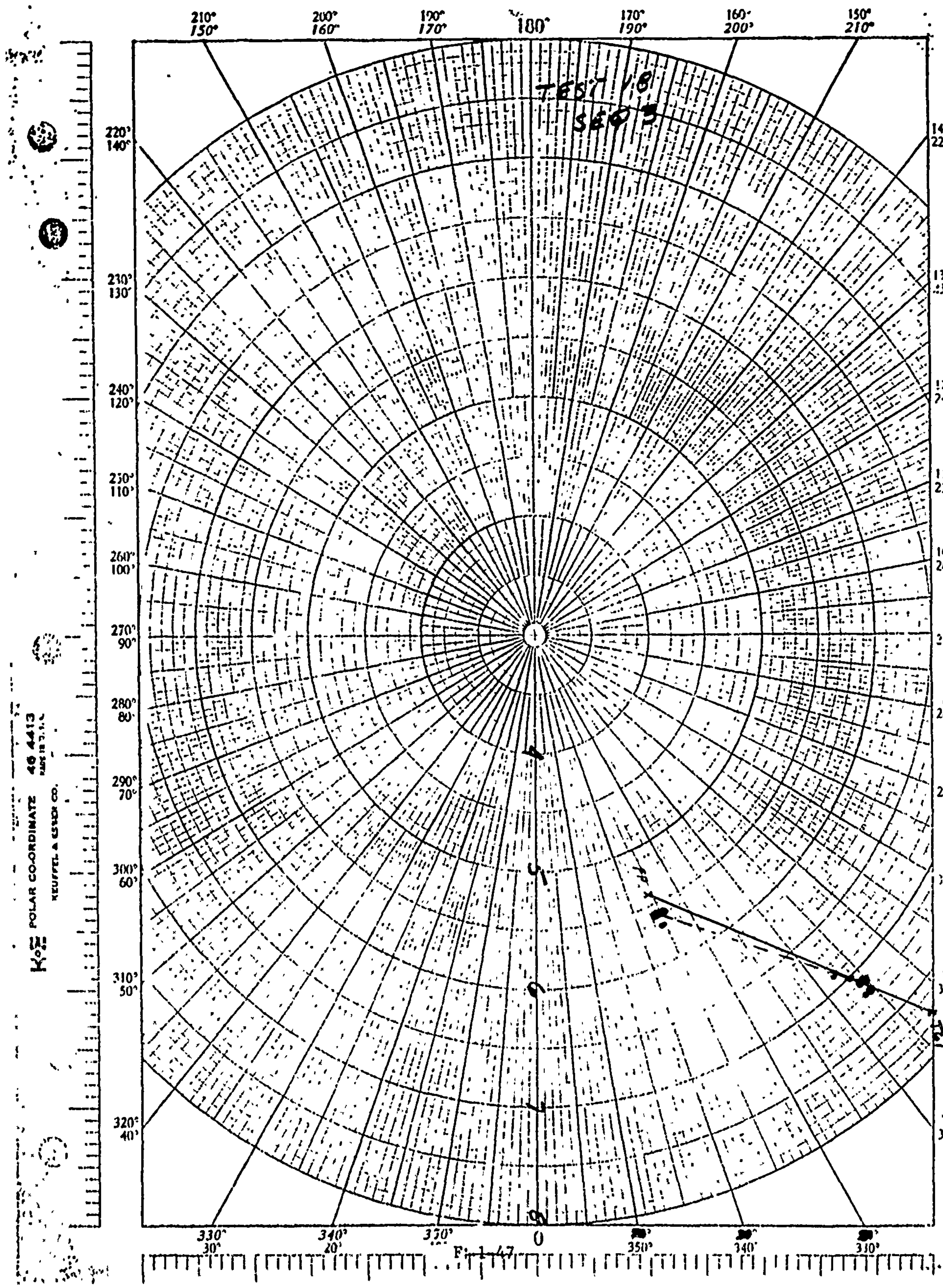
F-1-42


60°
70°
80°
90°
TEST 16
SEQ. 2
FP
TGT
R-1-43

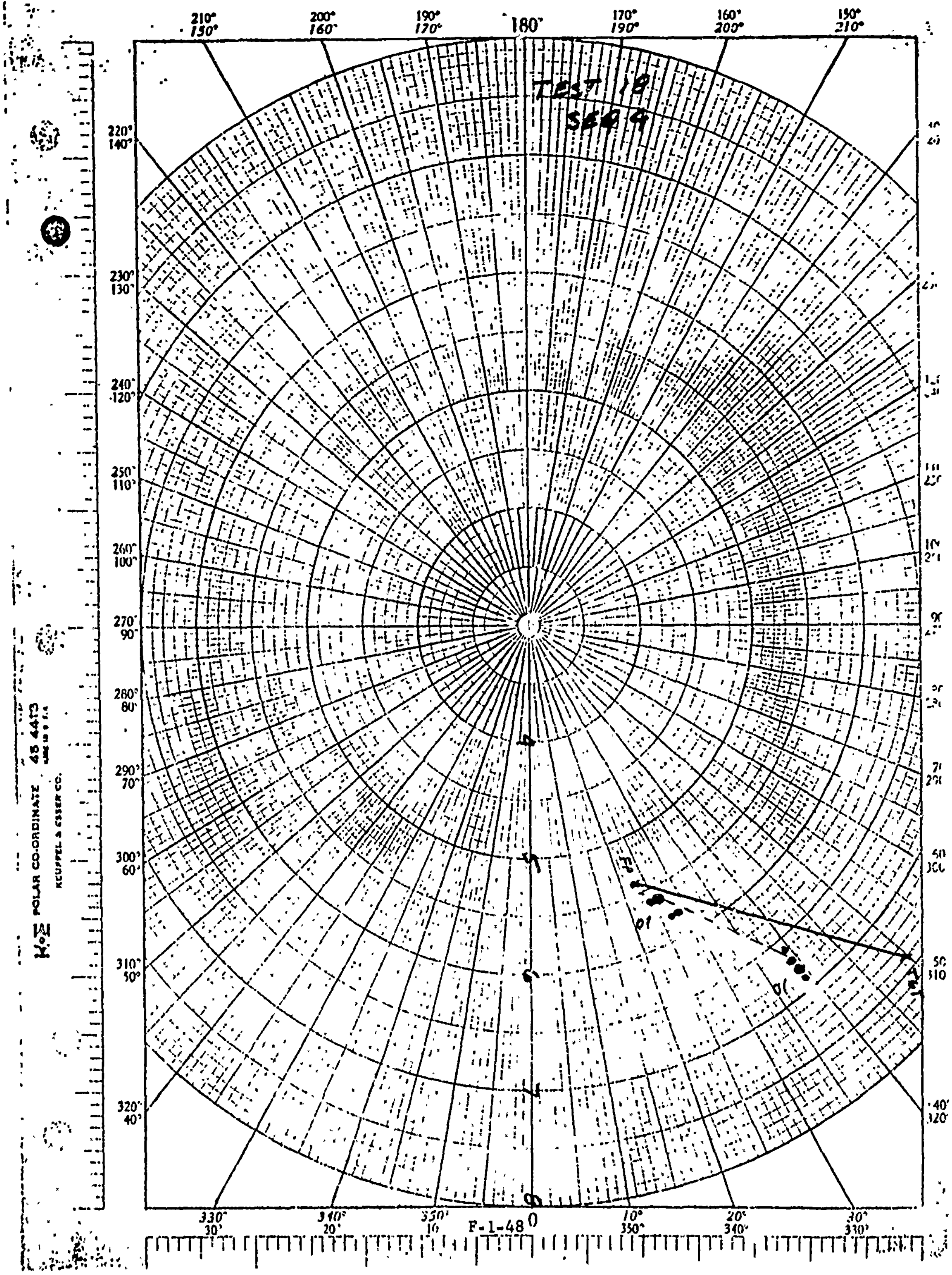

TEST 17
270
280
290
300
F-1-44
POLAR CO-ORDINATE 46 4413


TEST 1B
SEQ 1
180°
0
F-1-45
POLAR CO-ORDINATE 46 4413
KEUFFEL & ESSER CO.


TEST 18
SEQ 2
K&E POLAR CO-ORDINATE 46 4413
KEUFFEL & ESSER CO.
180°
0
F-1-46



F. 1-47


TEST 18
SEC 9
180°
170° 190°
160° 200°
150° 210°
200° 160°
210° 150°
190° 170°
220° 140°
230° 130°
240° 120°
250° 110°
260° 100°
270° 90°
280° 80°
290° 70°
300° 60°
310° 50°
320° 40°
330° 30°
340° 20°
350° 10
0
10° 350°
20° 340°
30° 330°
F-1-48
K+E POLAR CO-ORDINATE 46 4473
KEUFFEL & ESSER CO.

Appendix 2 - (Erroneous Tracks) to Annex F to Report of AN/TPQ-31 Performance During Evaluation as a Hostile Weapon Locator

ERRONEOUS TRACKS

The data for Test 9/1 at first appear puzzling because the predicted detection curves indicate that good results should be obtained. However, the miss distance averages for this group are among the worst of all the data. A look at the polar plots for 9/1 reveal that there is a strong possibility that a different test shot firing from a range of approximately 8.5 km (FP-387) was observed in error. The first and last detections are typically at approximately 8.3 km and 6.6 km respectively. The true projectile should have produced 8-9 detections during the detectable flight time, four of which would be during the observed range (8.3 km to 6.6 km). The raw data gives an average of 7.3 detections during the observed range indicating that the target tracked was not the correct one, and in all probability originated at FP-387.

A similar analysis was conducted for certain other samples of data where very evident inconsistencies were noted among the detection curves, miss distances and polar plots. In those cases where the observed number of scans separating the first and last blip differed by over 50% from the true value obtained from the computer simulation, the shots were considered wrong identifications and removed from the averages for miss distances. The following rounds fall into this category:

Tests

7/1	one erroneous round
7/2	one erroneous round
7/3	one erroneous round
7/4	two erroneous rounds
8	four erroneous rounds
9/1	all rounds erroneous
9/4	all rounds erroneous
12/3	all rounds erroneous

Appendix 3 - (Test Analysis Parameters) to Annex F to Report of AN/TPQ-31 Performance During Evaluation as a Hostile Weapon Locator

TEST ANALYSIS PARAMETERS

The following data lists some of the parameters for each test plus some pertinent comments. A brief explanation of the headings are as follows:

1. Test Type: Test types are either confirm or locate. For confirm tests, the general firing point and target area are known in advance. For locate tests, no information is given, and any trajectory observed is the recorded trajectory.

2. Weapon Type: (Self explanatory).

3. Range to Weapon: (Self explanatory).

4. Miss Distance:

   a. Operator Prediction: The miss distance is computed by back-plotting the track on a map.

   b. Machine Prediction: A calculator performs the equivalent of the above, but adds in a correction for the mask angle.

5. Blip Scan %: This is the observed ratio of the number of scans on which the targets were seen to the total number of scans during which the target was in the air.

6. Predicted Detection Curve: This is a prediction, arrived at by computer simulation, of the expected signal to noise ratio above a minimum detectable signal for the particular firing plotted for every 2 second (radar data rate) interval. Taken into account for this simulation are:

   a. Range to target

   b. Elevation to target and beam pattern

c. Instantaneous aspect and pitch of the projectile and its corresponding radar cross section

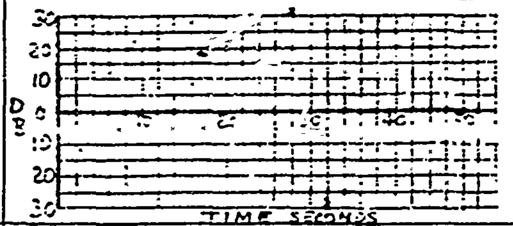
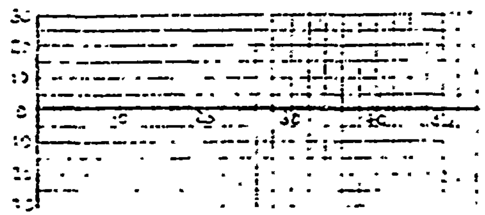
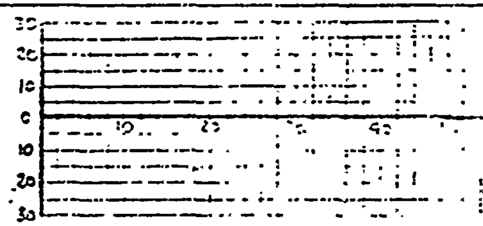
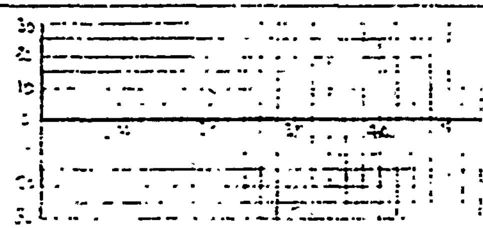
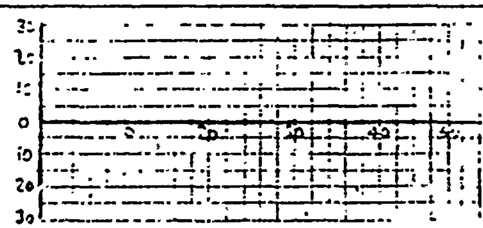
d. Range rate and the velocity notch

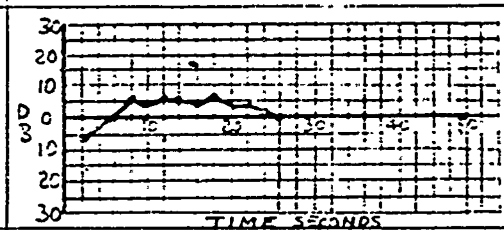
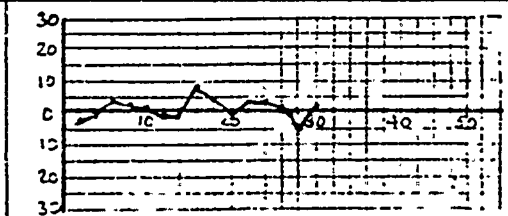
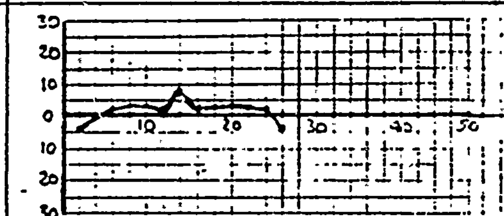
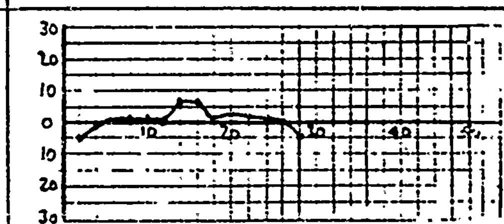
e. Sensitivity vs time control (STC) attenuation

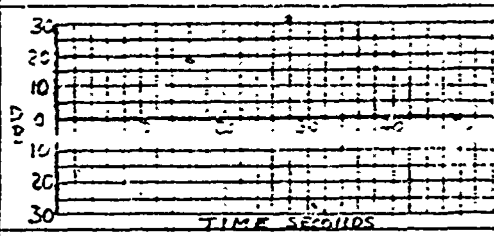
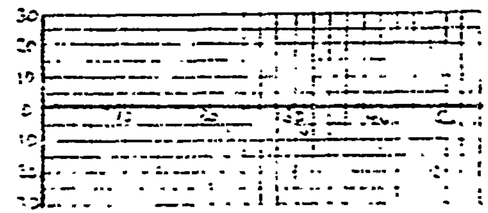
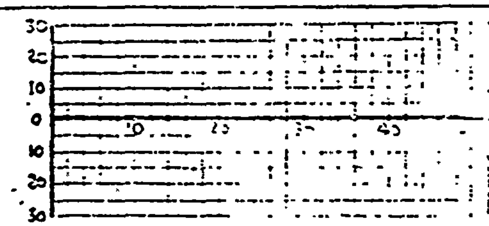
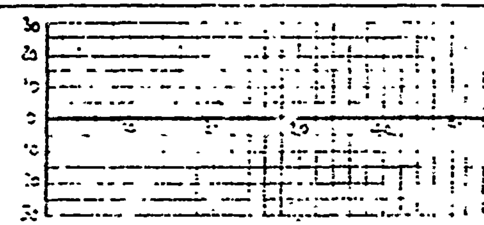
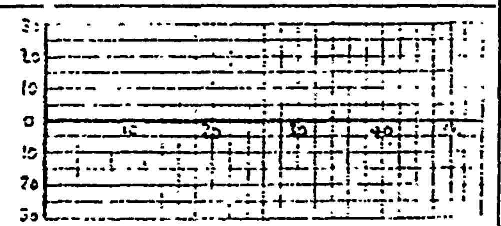
f. Weapon type, QE, charge, initial range, initial aspect

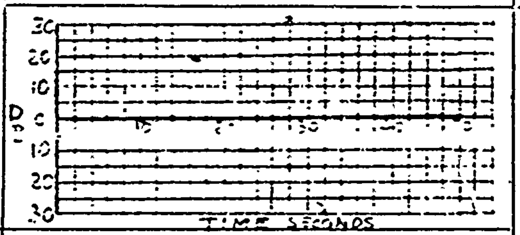
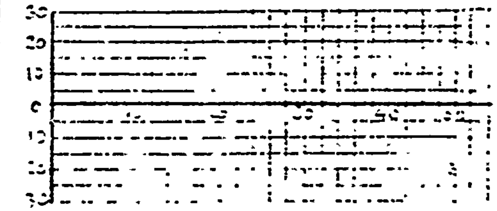
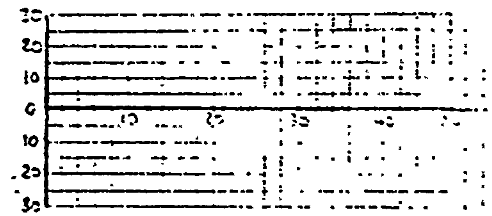
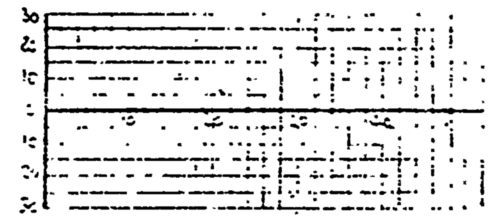
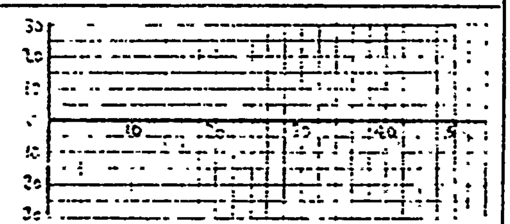
g. Slant range (2 second intervals).

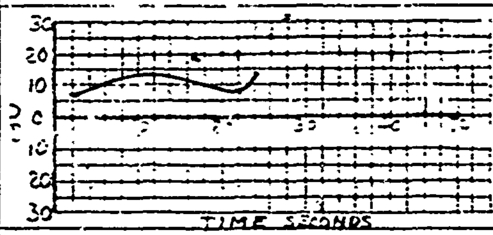
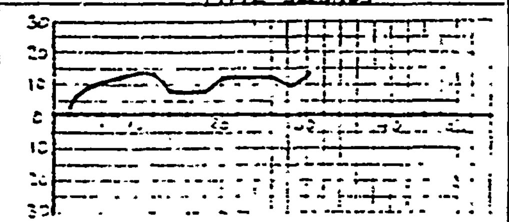
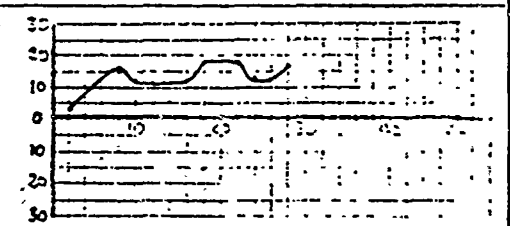
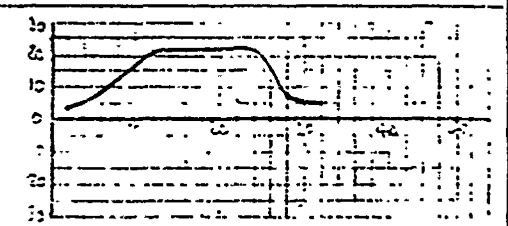
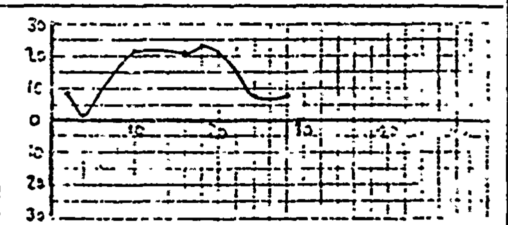
7. Comments: (Self explanatory).

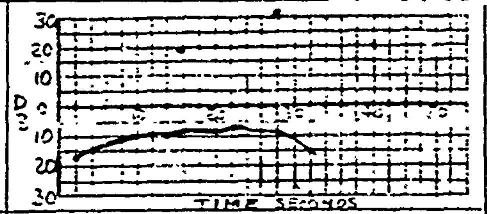
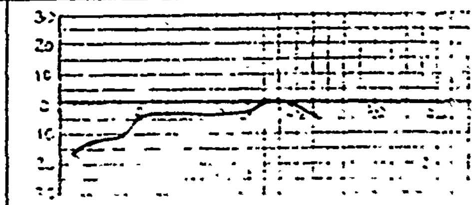
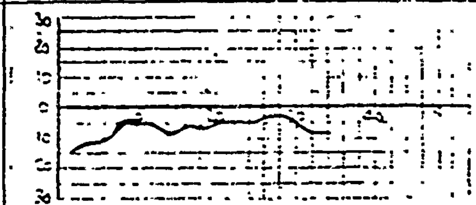
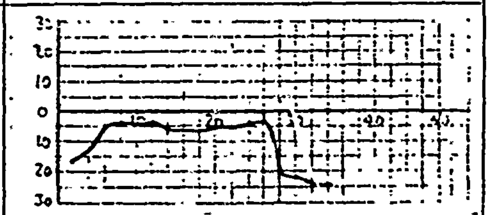
Test # / Seq #	Test Type	Wea. Type	Range to Wea.	Miss Distance Op. Pred.	Miss Distance Mach. Pred.	Blip Scan %	Predicted Detection Curve	Comments
2/1	Con-firm	4.2" Mor-tar	8.2 Km	-	-	0		Firings 2/1 thru 2/5 not detected. Locally supplied Army generator failed causing problems with short range display.
2/2	Con-firm	4.2" Mor-tar	8.2 Km	-	-	0		
2/3	Con-firm	4.2" Mor-tar	8.2 Km	-	-	0		
2/4	Con-firm	4.2" Mor-tar	8.2 Km	-	-	0		
2/5	Con-firm	4.2" Mor-tar	8.2 Km	-	-	0		

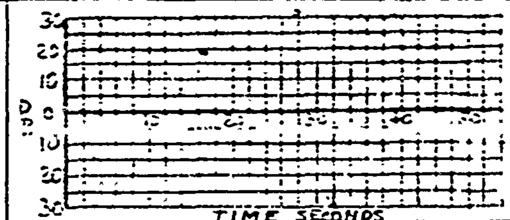
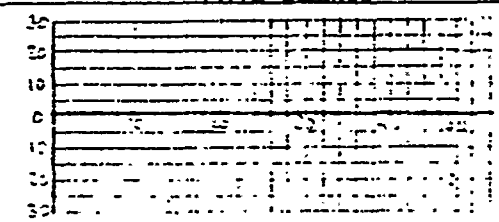
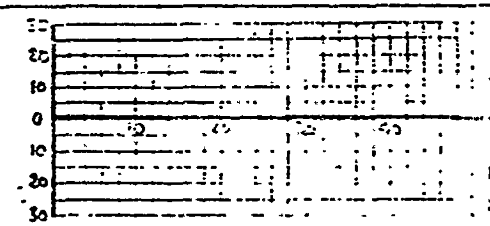
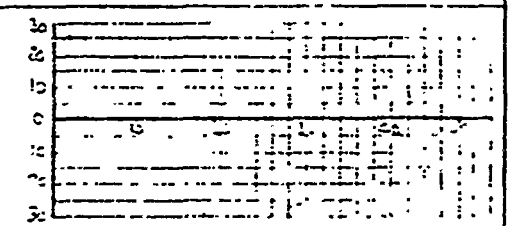
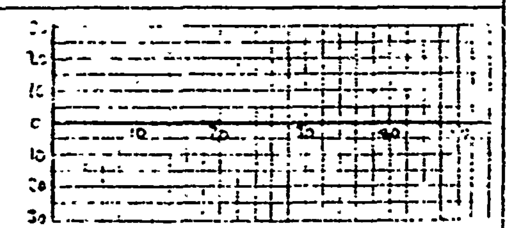
Test # / Seq #	Test Type	Wea. Type	Range to Wea.	Miss Distance Op. Pred.	Miss Distance Mach. Pred.	Blip Scan %	Predicted Detection Curve	Comments
2A/1	Con-firm	4.2" Mor-tar	13.25 Km	330.0 meters	360.8 meters	28%		The 2A/1 thru 2A/5 are characterized by non-detectability during the first 6 seconds of flight. The low detectability may be attributed to distance from weapon. Best M. Dist.: 149 m
2A/2	Con-firm	4.2" Mor-tar	13.25 Km	389.0 meters	732.6 meters	26%		This firing showed a strong azimuth bias, see polar plot, Appendix G-1 Best M. Dist.: 378 m
2A/3	Con-firm	4.2" Mor-tar	13.25 Km	462.0 meters	596.0 meters	36%		Best M. Dist.: 508 m
2A/4	Con-firm	4.2" Mor-tar	13.25 Km	520.0 meters	667.0 meters	37%		Best M. Dist.: 529 m
2A/5	Con-firm	4.2" Mor-tar	13.25 Km	440.0 meters	802.3 meters	31%		This firing showed a strong azimuth bias, see Appendix G-1 Best M. Dist.: 681 m

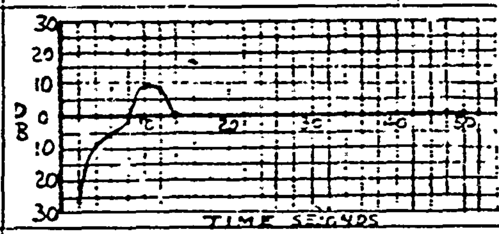
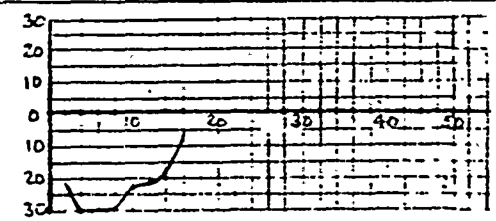
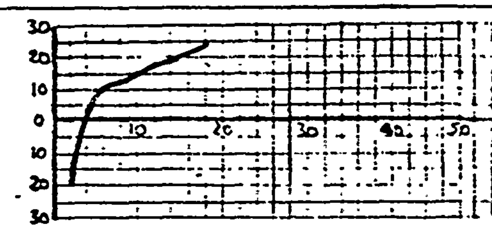
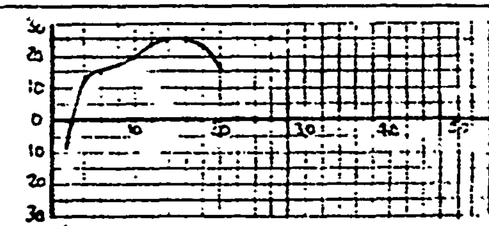
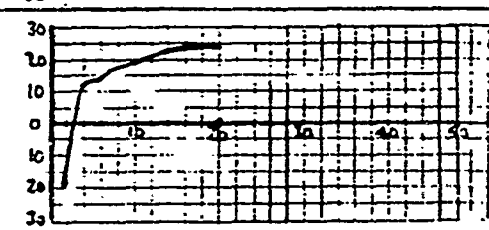
Test #/Seq #	Test Type	Wea. Type	Range to Wea.	Miss Distance Op. Pred.	Miss Distance Mach. Pred.	Blip Scan %	Predicted Detection Curve	Comments
2B/1	Con-firm	4.2" Mor-tar	4.45 Km	-	-	0		Firings 2B/1 thru 2B/5 had a radar problem - shorted wire (burnt out) in distribution box. See Appendix 4, Annex F.
2B/2	Con-firm	4.2" Mor-tar	4.45 Km	-	-	0		
2B/3	Con-firm	4.2" Mor-tar	4.45 Km	-	-	0		
2B/4	Con-firm	4.2" Mor-tar	4.45 Km	-	-	0		
2B/5	Con-firm	4.2" Mor-tar	4.45 Km	-	-	0		

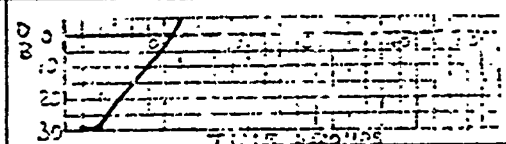
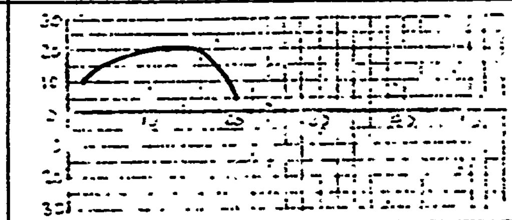
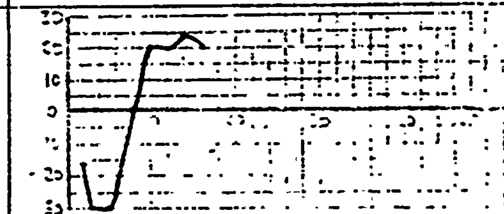
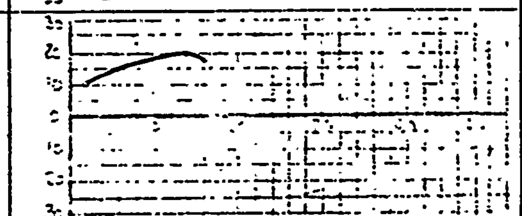
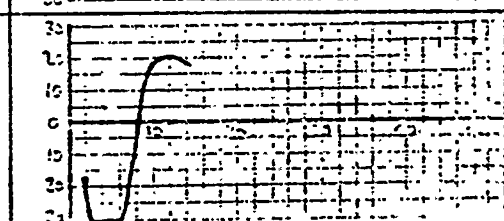
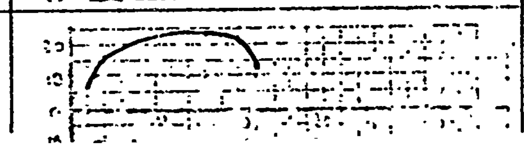
Test # / Seq #	Test Type	Wea. Type	Range to Wea.	Miss Distance Op. Pred.	Miss Distance Mach. Pred.	Blip Scan %	Predicted Detection Curve	Comments
3/1	Lo-cate	4.2" Mor-tar	13.4 Km	-	-	0		The firings 3/1 thru 3/5 were missed because of problems with locally supplied Army generators. Problem with short range display - instability in horiz. sweep circuit was also encountered.
3/2	Lo-cate	4.2" Mor-tar	13.4 Km	-	-	0		
3/3	Lo-cate	4.2" Mor-tar	13.4 Km	-	-	0		
3/4	Lo-cate	4.2" Mor-tar	13.4 Km	-	-	0		
3/5	Lo-cate	4.2" Mor-tar	13.4 Km	-	-	0		

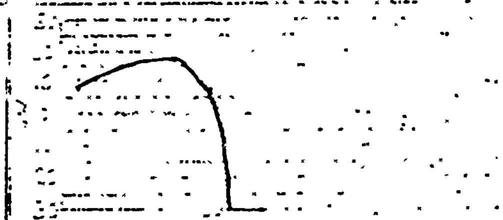
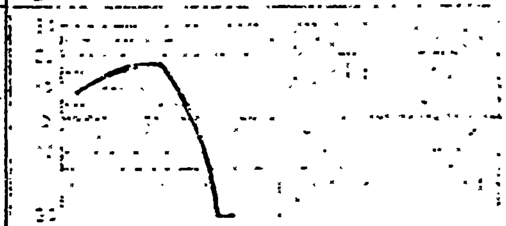
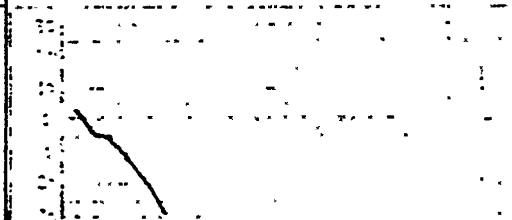
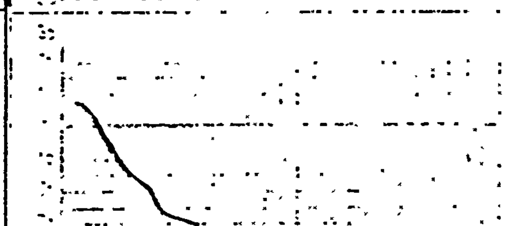
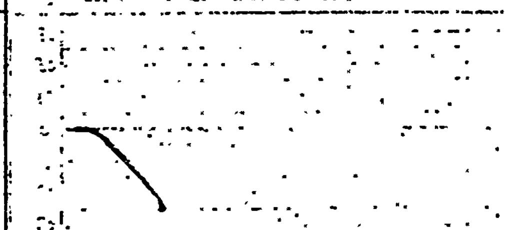
Test # / Seq #	Test Type	Wea. Type	Range to Wea.	Miss Distance Op. Pred.	Miss Distance Mach. Pred.	Blip Scan %	Predicted Detection Curve	Comments
3A/1	Lo-cate	4.2" Mor-tar	8.02 Km	417.0 meters	334.8 meters	79%		Firings 3A/1 thru 3A/5 show a high predicted probability of detection over the complete trajectories and the observed blip scan ratios were correspondently high - normally 90%. Best M. Dist.: 164 m
3A/2	Lo-cate	4.2" Mor-tar	8.02 Km	470.0 meters	379.1 meters	90%		Best M. Dist.: 252 m
3A/3	Lo-cate	4.2" Mor-tar	8.02 Km	484.0 meters	528.0 meters	90%		Best M. Dist: 413 m
3A/4	Lo-cate	4.2" Mor-tar	8.02 Km	434.0 meters	472.0 meters	92%		Best M. Dist.: 337 m
3A/5	Lo-cate	4.2" Mor-tar	8.02 Km	314.0 meters	292.4 meters	88%		Best M. Dist: 242 m

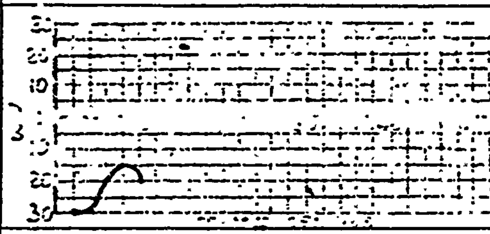
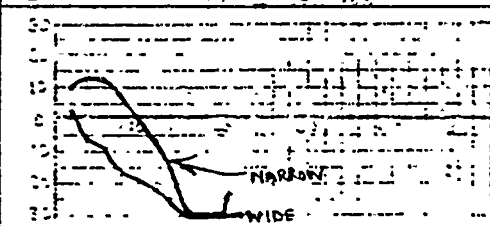
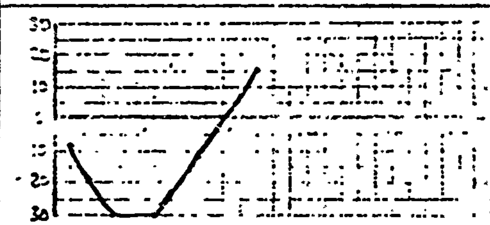
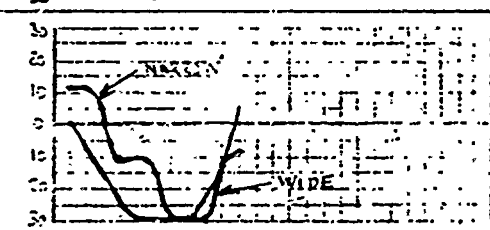
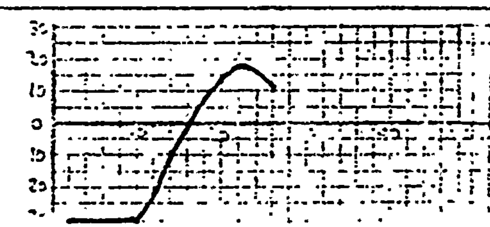
Test # / Seq #	Test Type	Wea. Type	Range to Wea.	Miss Distance Op. Pred.	Miss Distance Mach. Pred.	Blip Scan %	Predicted Detection Curve	Comments
3B/1	Lo-cate	4.2" Mor-tar	23.23 Km	640.0 meters	885.8 meters	23%		The 3B/1 thru 3B/5 firings started at 23 Km and ended at 19 Km ranges. Therefore, the prediction curves are generally below the threshold. The blip scan percentages were low (generally 20%) as expected resulting in large miss distances. Best M. Dist.: 885.8 m
3B/2	Lo-cate	4.2" Mor-tar	23.23 Km	746.0 meters	915.8 meters	23%		Best M. Dist.: 758 m
3B/3	Lo-cate	4.2" Mor-tar	23.23 Km	900.0 meters	1172.4 meters	23%		Best M. Dist.: 1172.4 m
3B/4	Lo-cate	4.2" Mor-tar	23.23 Km	828.0 meters	902.1 meters	23%		Best M. Dist.: 821.6 m
3B/5	Lo-cate	4.2" Mor-tar	23.23 Km	792.0 meters	858.9 meters	17%		Best M. Dist.: 804.6 m

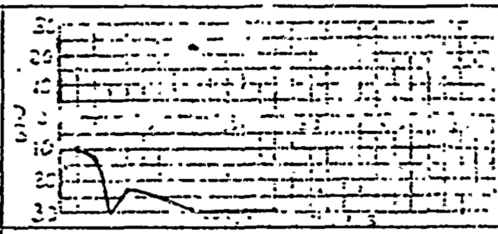
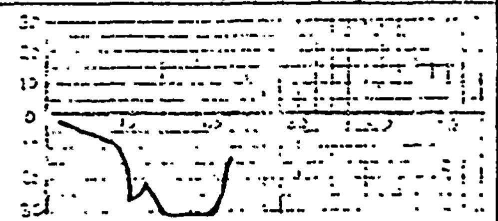
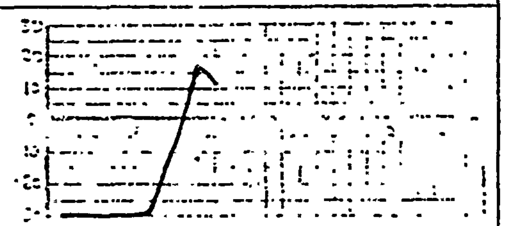
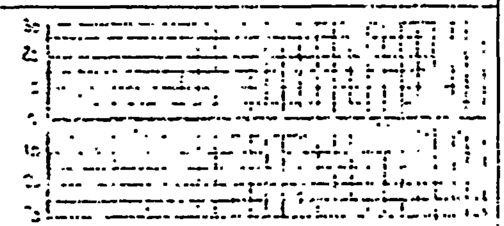
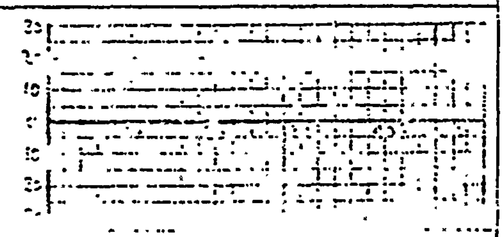
Test # / Seq #	Test Type	Wea. Type	Range to Wea.	Miss Distance Op. Pred.	Miss Distance Mach. Pred.	Blip Scan %	Predicted Detection Curve	Comments
4/1	Weapon Ident	155mm How.	14.05 Km	-	-	0		Problem with antenna pedestal. Bad brush, oil leak and partially siezed bearing.
4/2	Weapon Ident	4.2" Mortar	14.05 Km	-	-	0		
4/3	Weapon Ident	105mm How.	14.05 Km	-	-	0		
4/4	Weapon Ident	175mm Gun	14.05 Km	-	-	0		
								

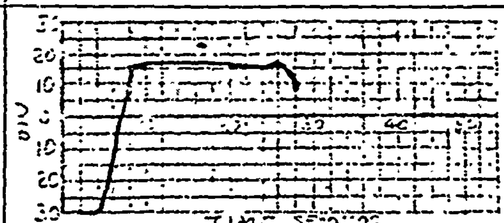
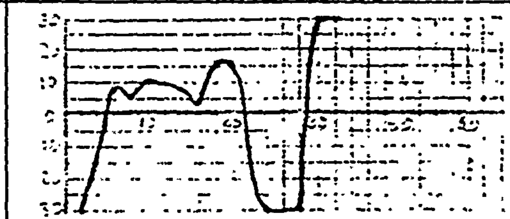
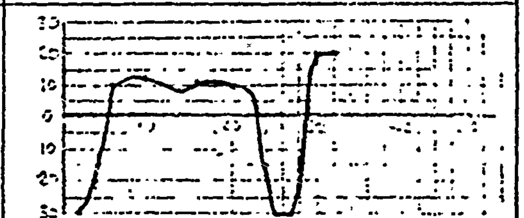
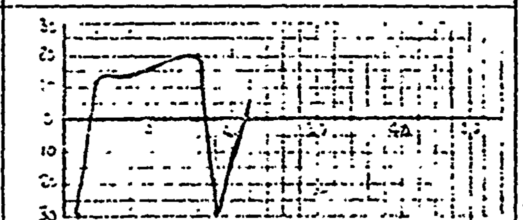
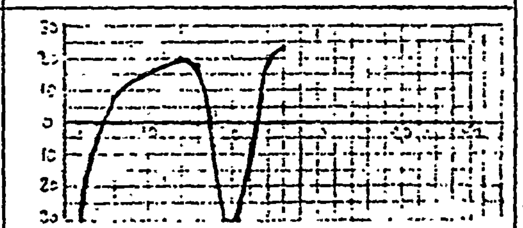
Test # / Seq #	Test Type	Wea. Type	Range to Wea.	Miss Distance Op. Pred.	Miss Distance Mach. Pred.	Blip Scan %	Predicted Detection Curve	Comments
5/1	Con-firm	105mm How.	10.4 Km	1293 meters	537.1 meters	30%		Firings 5/1 thru 5/5 initial trajectories were velocity blind resulting in initial detection being too late to permit meaningful firing point prediction. Best M. Dist.: 463.9 m
5/2	Con-firm	105mm How.	10.4 Km	-	-	0%		These firings never were above detection threshold.
5/3	Con-firm	105mm How.	10.4 Km	1693 meters	1173.1 meters	59%		Best M. Dist.: 1150 m
5/4	Con-firm	105mm How.	10.4 Km	2163 meters	787.0 meters	83%		Best M. Dist.: 339 m
5/5	Con-firm	105mm How.	10.4 Km	1106 meters	230.1 meters	88%		Best M. Dist.: 622 m

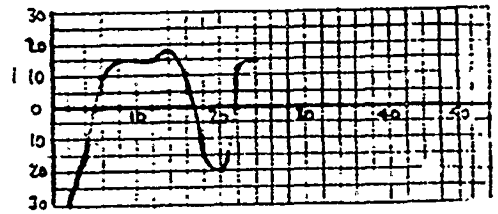
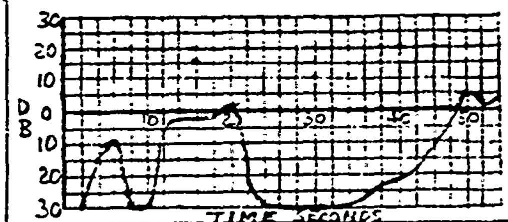
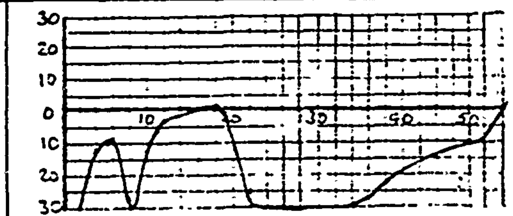
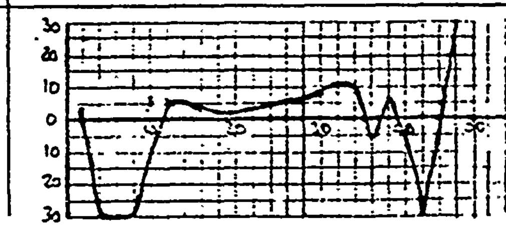
Test # / Seq #	Test Type	Wea. Type	Range to Wea.	Miss Distance Op. Pred.	Miss Distance Mach. Pred.	Blip Scan %	Predicted Detection Curve	Comments
6	Lo-cate	105mm How.	10.25 Km	-	-	0		All these firings were in velocity notch, therefore not seen.
7/1	Con-firm	105mm How.	10.44 Km	1015.0 meters	836.1 meters	87%		Wrong track out Miss dist. 363 m Best M. Dist.: 259 m
7/2	Con-firm	105mm How.	10.44 Km	880.0 meters	630.0 meters	74%		Wrong track out Miss dist. 124 m Best M. Dist.: 135 m
7/3	Con-firm	105mm How.	10.44 Km	1316.0 meters	820.5 meters	72%		Wrong track out Miss dist. 346 m Best M. Dist.: 155 m
7/4	Con-firm	105mm How.	10.44Km	2008.0 meters	1584.1 meters	78%		Wrong track out Miss dist. 803 m Best M. Dist.: 658 m
◇	Con-firm	155mm How.	10.44Km	1030.0 meters	449.3 meters	77%		This series of firings show good predicted detectability. Miss distance results are poor as operators tracked rounds not associated with test. Best M. Dist.: 66.7 m

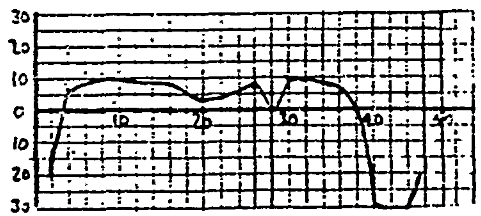
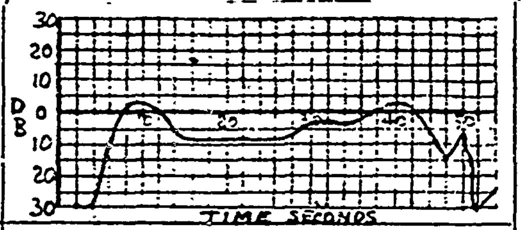
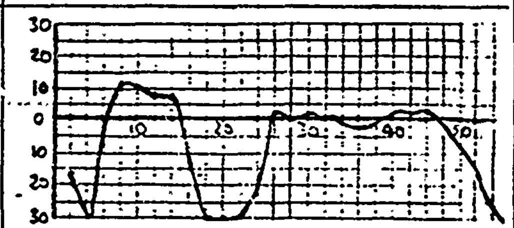
Test # / Seq #	Test Type	Wea. Type	Range to Wea.	Miss Distance Op. Pred.	Miss Distance Mach. Pred.	Blip Scan %	Predicted Detection Curve	Comments
9/1	Lo-cate	105mm How.	11.35 Km	2870.0 meters	3180.0 meters	37%		In firings 9/1 thru 9/2, operator tracked some rounds not associated with test. These non-valid tracks were interspersed in the collected data which led to large miss distances. Best M. Dist.: 2884 m
9/2	Lo-cate	105mm How.	10.7 Km	1376.0 meters	1731.0 meters	77%		Best M. Dist.: 357 m
9/3	Lo-cate	105mm How.	8.36 Km	534.0 meters	384.6 meters	63%		Best M. Dist.: 140 m
9/4	Lo-cate	105mm How.	9.5 Km	1200.0 meters	2050.8 meters	39%		Firing 9/4 shows influence of non-valid rounds as the predicted detectability indicates no round should have been seen. Best M. Dist.: 1360 m
9/5	Lo-cate	105mm How.	8.2 Km	-	-	0		Firings 9/5 and 9/6 show detection was not possible.

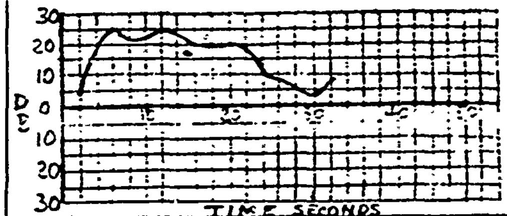
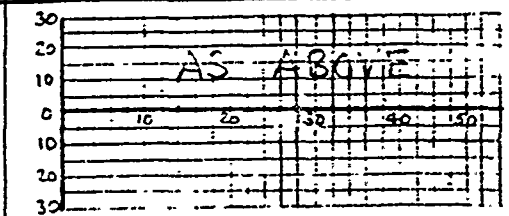
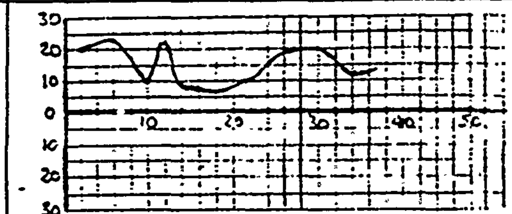
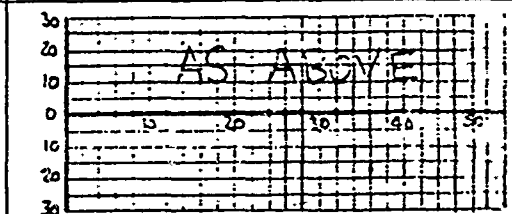
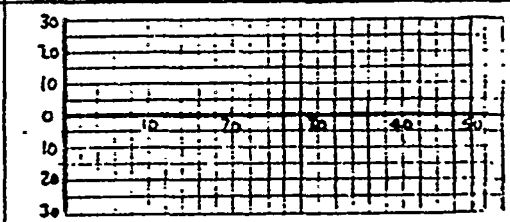
Test # / Seq #	Test Type	Wea. Type	Range to Wea.	Miss Distance Op. Pred.	Miss Distance Mach. Pred.	Blip Scan %	Predicted Detection Curve	Comments
9/6	Lo-cate	105mm How.	7.4 Km	-	-	0		
10/1	Con-firm	105mm How.	9.95 Km	563.0 meters	594.4 meters	51%		The prediction curve shows poor detectability return & falling in the clutter notch regardless of whether wide or narrow notch was used. This condition also contributes to scatter on polar plot, Appendix 1, Annex F. Best M. Dist.: 203 m
10/2	Con-firm	105mm How.	9.95 Km	-	-	0		Same as above all but last 4 seconds out of clutter notch. The generator also stopped which killed the keep alive voltage causing loss of receiver crystals of a local radar.
11/1	Lo-cate	105mm How.	9.3 Km	955.0 meters	866.8 meters	20%		Firings 11/1 and 11/2 are also almost completely in clutter notch causing low blip to scan ratios, which lead to large miss distances. Best M. Dist.: 284 m
11/2	Lo-cate	105mm How.	9.3 Km	3741.0 meters	3032.2 meters	11%		Best M. Dist: 1104 m

Test #/Seq #	Test Type	Wea. Type	Range to Wea.	Miss Distance Op. Pred.	Miss Distance Acc. Pred.	Slip Scan %	Predicted Detection Curve	Comments
12/1	Lo-cate	105mm How.	10.65 Km	1700.0 meters	1323.9 meters	65%		Firings 12/1 thru 12/3 are in the velocity notch resulting in low detectability and excessive miss distances. Best M. Dist.: 194 m
12/2	Lo-cate	105mm How.	9.55 Km	950 meters	532.0 meters	29%		In addition to low detectability 12/2 and 12/3 displayed excessive azimuth biases on the polar plot, Appendix 1, Annex F. This is result of tracking non-valid rounds. Best M. Dist.: 172 m
12/3	Lo-cate	105mm How.	8.8 Km	2334.0 meters	2259.0 meters	27%		Best M. Dist.: 1321 m
								
								

Test # / Seq #	Test Type	Wea. Type	Range to Wea.	Miss Distance Op. Pred.	Miss Distance Mach. Pred.	Blip Scan %	Predicted Detection Curve	Comments
13/1	Lo-cate	155mm How.	11.6 Km	680.0 meters	591.2 meters	36%		Firings 13/1 thru 13A/2 all show a normal 5-7 second delay because of the velocity notch. The plotted and machine miss distances are normally comparable, as they should be. Best M. Dist.: 591 m
13/2	Lo-cate	155mm How.	11.6 Km	440.0 meters	332.1 meters	19%		Best M. Dist.: 332 m
13/3	Lo-cate	155mm How.	11.6 Km	450.0 meters	467.1 meters	19%		Best M. Dist.: 467 m
13A/1	Lo-cate	155mm How.	10.15 Km	216.0 meters	210.4 meters	80%		Best M. Dist.: 126 m
13A/2	Lo-cate	155mm How.	10.15 Km	173.0 meters	149.5 meters	59%		Best M. Dist.: 155 m

Test # / Seq #	Test Type	Wea. Type	Range to Wea.	Miss Distance Op. Pred.	Miss Distance Mach. Pred.	Blip Scan %	Predicted Detection Curve	Comments
13A/3	Lo-cate	155 mm	10.15 Km	68.0	120.0	36%		Best M Dist: 81 m
14	Check Out	175mm Gun	29.7 Km	-	-	0		The firings 14 thru 15/2 show virtually no detections possible, and none were observed. These firings were essentially out of range of the AN/TPQ-31.
15/1	Con-firm	175mm Gun	29.7 Km	-	-	0		
15/2	Con-firm	175mm Gun	29.7 Km	-	-	0		
15A/1	Con-firm	8.0" How.	16.05 Km	-	-	0		Although more than 50% of the time of flight is predicted to be detectable, none of the firings were seen because of poor signal to noise ratios.

Test # / Seq #	Test Type	Wea. Type	Range to Wea.	Miss Distance Op. Pred.	Miss Distance Mach. Pred.	Blip Scan %	Predicted Detection Curve	Comments
15A/2	Con-firm	8.0" How.	16.05 Km	1024.0 meters	816.2 meters	28%		The predicted detection is somewhat improved over 15A/1 but the polar plots Appendix 1, Annex F show an azimuth bias contributing to the large miss distances. Best M. Dist.: 532 m
16/1	Lo-cate	8.0" How.	17.1 Km	-	-	0		Prediction detection for 16/1 and 16/2 are very poor as these rounds were in the clutter notch and high in the radar beam.
16/2	Lo-cate	8.0" How.	15.4 Km	416.0 meters	136.3 meters	25%		Best M. Dist.: 93 m
17	Con-firm	175 mm How.	5.6 Km	280.0 meters	155.0 meters	10%		Although very poor detectability is indicated for these firings because of clutter notch, decent miss distances were attained helped by the remarkably bias free situation in polar plot Appendix 1, Annex F. Best M. Dist.: 128 m

Test # / Sec #	Test Type	Wea. Type	Range to Wea.	Miss Distance Op. Pred.	Miss Distance Mach. Pred.	Blip Scan %	Predicted Detection Curve	Comments
18/1	Con-firm	4.2" Mor-tar	5.4 Km	180.0 meters	165.0 meters	63%		The firings 18/1 thru 18/4 show good detectability. The miss distances were adversely affected by azimuth bias particularly 18/4. See polar plot, Appendix 1, Annex F. Best M. Dist.: 51 m
18/2	Con-firm	4.2" Mor-tar	5.4 Km	130.0 meters	161.6 meters	55%		Best M. Dist.: 139 m
18/3	Con-firm	81mm Mor-tar	5.4 Km	175.0 meters	195.0 meters	50%		Best M. Dist.: 148 m
18/4	Con-firm	81 mm Mor-tar	5.4 Km	300.0 meters	294.0 meters	41%		Best M. Dist.: 152 m
								

Appendix 4 - (Test Analysis Findings) to Annex F to Report of AN/TPQ-31 Performance During Evaluation as a Hostile Weapon Locator

TEST ANALYSIS FINDINGS

TEST 2 Radar problems - See Appendix 5, Annex F.

TEST 2A These firings are characterized by non-detectability for approximately the first 6 seconds after firing. The detectability was low due to the distance to the weapon. A glance at the polar plots shows strong azimuth biases for 2A/2 to 2A/5. Since there are no mask angles, the machine and operator predictions must agree within the limits allowed by map plotting accuracy. Because of such unavoidable errors, the operator predictions should have miss distances generally showing equal probability for being greater or less than the correct value. The operator values do exhibit such a distribution. The low blip-scan percentage is consistent with the generally weak detectability prediction. It should be noted that operator miss distances were based not on the number of target blips N, but on the total number of scans during the time the target was in flight. As a result, some scans are counted prior to target detection by radar. On confirm tests the blip scan count was started from the moment the crew was given the "round away" signal, and on the locate test the blip scan count was started from the radar first detection. If there was no radar detection on the confirm test a "0" was entered in the blip scan column, when the radar made a detection a "1" was entered. The "N" for computation of backtrack is the number of scans

between the first "1" and last "1", not necessarily the first scan the target is airborne to the last "1". This leads to a slight error in the operator miss distances but does not significantly affect the overall results.

TEST 2B

Antenna Problems Test 2B - This test was missed due to a problem with the Antenna. The first sign of the trouble was a burnt out wire in the distribution box. The wire was in the antenna drive motor neutral line. When the wire was replaced, the antenna would rotate but was a little reluctant to start on some occasions.

TEST 3

Short Range Display Problem, Tests 2 & 3 - Generators were a persistent problem during the test. The generator would run for a while and shut down. It was after such a generator failure that an intermittent fault in the short range display was experienced. When the system was cold the horizontal sweep was short, and unstable. After a warm-up period of approximately 30 mins., the display would settle down and function correctly. With the amount of time available to troubleshoot, the problem was not found. Cards were changed that were within the horizontal sweep and cursor circuits but the trouble remained. At the end of each work day the truck which housed the console was driven back to the motor pool at Fort Sill. This continuing agitation may have worsened the situation. The yoke driver assembly was a little burnt in the area of the 1Ω 1W series resistors. This assembly would have been changed or the drive

transistor replaced had the test not come to a close. In all probability this assembly was the cause of the problem.

TEST 3A These tests show a high predicted probability of detection over the complete trajectory and the observed blip scan ratios are correspondingly high - nominally 90%. The machine miss distances range between 292 meters and 528 meters, primarily as a result of a somewhat higher than average azimuth scatter. The operator predictions nominally fluctuate around the machine predictions as they should.

TEST 3B These tests were at an initial range of 23 km ending at 18 or 19 km and therefore show prediction curves generally below the threshold. The blip scan percentages were low (nominally 20%) as expected and the miss distances were correspondingly high, nominally 800 to 900 meters. The polar plots reveal relatively low biases which kept the miss distances from being much higher.

TEST 4 This test was adversely affected by antenna malfunction. The drive motor was removed from the pedestal and inspected. The armature bearing at the brush end was partially seized. This seizure was caused by the heat generated by one of the brushes. The brush was worn and the spring tension so small that the resultant arcing caused the heat. The motor was overhauled, armature bearing replaced and the bull ring bearings cleaned. After reassembly, the antenna functioned without any further problems.

TEST 5 In test 5, all prediction curves show the initial trajectory to be velocity blind. Test 5/2 simulations never rise above the threshold. Excellent correlation was obtained in the test results. The blip scan ratio for 5/2 was 0% and between 30% and 80% for the others, with seemingly close correlation to the simulations.

Test 5 had a 1.0° mask angle and consideration of this fact in machine predictions resulted in a significant improvement of miss distances. They range from 1693 (opr) vs 1173 (machine) to as good as 1106 (opr) vs 230 (machine). The firing data as listed on the operator's data sheet (F-5-22) are in reverse sequence order. Tgt 319 is Sequence 1, Tgt 307 is Sequence 2, etc.

TEST 6 The simulations put the test 6 trajectory in the velocity notch and this correlates with the observed blip scan ratio of 0%.

TEST 7 Test 7 results correlate well with the simulations except for 7/2 which came out better than expected. Both 7/2 and 7/4 started in the velocity notch. Once again, the machine miss distances were dramatically better than the operator miss distances because of the inclusion of mask angle correction.

Because of several different firings in the area during Test 7, operators had some difficulty picking the correct targets. This may account for some scatter in the results.

TEST 8 Test 8 simulations predict good detectability and such was the case (77% blip scan ratio). This test had a mask angle and the machine miss distance is less than half the value of the plotted miss distances. The biases were small and the corresponding

miss distances should have been low. A study of the polar plot was made, and one possibility is that wrong rounds were tracked for a part of the time. The observed projectile range rate was checked against the simulations, and a considerable discrepancy was found with four (4) rounds which could have originated from a non-participating firing point.

<u>TEST 9</u> Test 9 results show peculiar discrepancies in several different ways.

1. The observed blip scan ratios do not correlate well with the prediction plots (except for sequences 9/5 and 9/6 where the targets should not have been detected due to blind speed).
2. Seq 1 shows a miss distance of 3.100 km using given FP-347, but if in reality they were fired from FP-387 the error is reduced to .755 km due in part to the masking of Dodge Hill. The polar plot shows this could well be the case for Seq 1.
3. Seq 2. This group shows a dispersion due to the masking of Dodge Hill during the flight. Some detections were made at the early part of the trajectory (10.2 km) but most were grouped around 8.5 km where they came out from behind Dodge Hill. The radar had approximately a 1 second look at the early part of the trajectory before the masking effect of Dodge Hill was encountered.

4. Seq 3 shows good results although the detection curves are marginal.

5. Seq 4. Only two rounds were recorded, and they are widely scattered. The detection curve is marginal and it is a good probability that none of the rounds of Seq 4 were actually detected.

It was therefore concluded that Test 9 data is interspersed with tracks of projectiles which do not correspond with the scheduled firings. Since Test 9 is a locate test, all operator miss distances are based on taking the difference between the plotted backtrack point and a best known firing point. For Test 9, this best known point never corresponded to the actual firing point and so the operator miss distances listed are not valid.

TEST 10

The results for 10/1 show a relatively wide range and azimuth scatter in the polar plot and this is reflected in the miss distances 563 meters plotted, 594 meters machine. The prediction plots show poor detectability (due to the clutter notch) and this contributed to the scatter.

Test 10/2 is predicted to be in the clutter notch for all but the last 4 seconds.

However, the generator stopped before Seq 2, the loss of keep alive voltage led to a loss of the receiver crystals due to radiation from co-located L-band radar and no blips were observed.

TEST 11

Tests 11/1 and 11/2 are almost completely in the clutter notch and showed a blip scan ratio of 20% and 11% respectively. The correlation with the prediction curve is good. The rounds in Seq 11/1 had a better chance of being detected earlier than those in 11/2. This was indeed the case, and a corresponding improvement in miss distance was realized. Tests 11/2 was 3032 meters compared to 867 meters for 11/1. Once again a mask angle correction improved the machine results.

The narrow clutter notch was used for Test 11, and a detection curve based on the narrow notch corresponds well to the actual blip scans experienced.

TEST 12

Test 12 detection curve predicts no detections due to velocity notch and yet the target was seen (65%, 29% and 27% of the time for 12/1, 12/2 and 12/3 respectively). Tests 12/1 and 12/2 were masked. The mask correction used in the machine prediction produced significant improvements - 1700 meters (operator) to 1324 meters (machine), and 950 meters (operator) to 532 meters (machine).

The azimuth biases for 12/2 and 12/3 appear excessive on the polar plots, due in part to operators experimenting with leading edge and trailing edge of the painted blip. A test of projectile velocities compared with simulations lead to the conclusion that at least two tracks of 12/3 were not the scheduled projectile, therefore explaining the very large miss distances of 2334 and 2259 for operator plot and machine calculations.

TEST 13, 13A Test 13, 13A detection curves show that all rounds are detectable after a nominal 5-7 second delay due to the velocity notch. Test 13 mask angles were only 0.2° and had no significant effect on the prediction. The operator plotted and machine miss distances are nominally comparable, as they should be, and range from about 100 meters to about 600 meters.

TEST 14 The predicted detection curves show virtually no detectability. These firings were also essentially out of range of the AN/TPQ-31, resulting in no detections being made during this test.

TEST 15 Same as above.

TEST 15A Tests 15/A and 16 prediction curves were based on assumed data for a 8" howitzer, which apparently generated overly optimistic possibility of detection. Test 15A/1 curves predict detections over more than 50% of the time of flight. The signal to noise ratio was low and no detections were made.

Test 15A/2 curves show a somewhat improved situation. The target was approximately 10 dB above MDS for 50% of the flight and a 28% blip scan was recorded. The polar plots show a considerable azimuth bias which contributed to the machine miss distance of 816 meters.

TEST 16 Test 16 detection curves are generally very poor due to the target being in either the clutter notch or high in the antenna beam. Thus test 16/1 blip scar is 0 and 16/2 is 25%. Test 16/2 was masked and the machine predictions were significantly better than operator plotted predictions.

<u>TEST 17</u>

Test 17 detection curve predicts very poor detectability (clutter notch), which was confirmed by the 10% blip scan ratio. The polar plots of Test 17, however, show a remarkably bias free situation. This, plus the early detection of the target gave machine miss distance of 155 meters, even though a small percentage of the projectile flight was detected.

<u>TEST 18</u>

Test 18 curves show good detectability for all sequences and blip scans ranged somewhat lower than expected. Miss distances were very satisfactory, however, between 161 meters and 195 for the first 3 sequences. The polar plot for 18/4 shows a significant bias and led to a miss distance of 294 meters.

Appendix 5 - (Recorded Test Data from Ft. Sill Tests) to Annex F of Report of AN/TPQ-31 Performance Evaluation as a Hostile Weapon Locator

TEST # / SEQ #	NUMBER OF ROUNDS	WEAPON				RADAR				
		TYPE	QE MILS	CHARGE	M.V. M/S	RANGE TO WEAPON	INITIAL ASPECT ANGLE W.R.T.R.	MASK ANGLE	WEATHER	
2/1	5	4.2"	900	17.0	194.6	8.2 KM	8.0°		CLEAR COLD	23 JAN 73 AM
2/2	5	4.2"	900	$12\frac{4}{8}$	162.1	8.2 KM	15.0°		"	"
2/3	5	4.2"	900	$19\frac{2}{8}$	210.0	8.2 KM	0.75°		"	"
2/4	5	4.2"	900	$13\frac{2}{8}$	167.0	8.2 KM	1.0°		"	"
2/5	5	4.2"	900	19.0	209.0	8.2 KM	17.0°		"	"
2A/1	5	4.2"	900	17.0	194.6	13.25 KM	18.0°	0°	"	23 JAN 73 PM
2A/2	5	4.2"	900	$20\frac{4}{8}$	219.8	13.25 KM	29.0°	0°	"	"
2A/3	5	4.2"	900	$15\frac{4}{8}$	183.8	13.25 KM	24.5°	0°	"	"
2A/4	5	4.2"	900	19.0	209.0	13.25 KM	25.0°	0°	"	"
2A/5	5	4.2"	900	$17\frac{4}{8}$	198.2	13.25 KM	27.0°	0°	"	"
2B/1	5	4.2"	900	$14\frac{4}{8}$	176.5	4.45 KM	27.0°		"	24 JAN 73 AM
2B/2	5	4.2"	900	16.0	187.4	4.45 KM	37.0°		"	"
2B/3	5	4.2"	900	$17\frac{4}{8}$	198.2	4.45 KM	46.0°		"	"
2B/4	5	4.2"	900	$19\frac{4}{8}$	212.6	4.45 KM	32.0°		"	"
2B/5	5	4.2"	900	19.0	209.0	4.45 KM	22.0°		"	"

TEST # / SEQ #	NUMBER OF ROUNDS	WEAPON				RADAR				
		TYPE	QE MILS	CHARGE	M.V. M/S	RANGE TO WEAPON	INITIAL ASPECT ANGLE W.R.T.R.	MASK ANGLE	WEATHER	
3/1	5	4.2"	900	13 4/8	169.3	13.4 KM	31.0°		CLOUDY COLD	26 JAN 73 AM
3/2	5	4.2"	900	15 4/8	183.8	13.4 KM	39.0°		"	"
3/3	5	4.2"	900	20 4/8	219.8	13.4 KM	35.0°		"	"
3/4	5	4.2"	900	20 4/8	219.8	13.4 KM	30.0°		"	"
3/5	5	4.2"	900	16.0	187.4	13.4 KM	13.0°		"	"
3A/1	5	4.2"	900	12.0	158.5	8.1 KM	25.0°	0°	"	26 JAN 73 PM
3A/2	5	4.2"	900	18 4/8	205.4	8.1 KM	23.0°	0°	"	"
3A/3	5	4.2"	900	16.0	187.4	8.1 KM	17.0°	0°	"	"
3A/4	5	4.2"	900	19 4/8	212.6	8.1 KM	8.0°	0°	"	"
3A/5	5	4.2"	900	16.0	187.4	8.1 KM	7.0°	0°	"	"
3B/1	5	4.2"	900	22.0	230.6	23.23 KM	25.0°	0°	CLEAR COLD	24 JAN 73 PM
3B/2	5	4.2"	900	21 4/8	227.0	23.23 KM	17.5°	0°	"	"
3B/3	5	4.2"	900	24.0	245.0	23.23 KM	4.0°	0°	"	"
3B/4	5	4.2"	900	22 4/8	234.2	23.23 KM	20.5°	0°	"	"
3B/5	5	4.2	900	22 4/8	234.2	23.23 KM	16.0°	0°	"	"

TEST # / SEQ #	NUMBER OF ROUNDS	WEAPON				RADAR			WEATHER	
		TYPE	QE MILS	CHARGE	M.V. M/S	RANGE TO WEAPON	INITIAL ASPECT ANGLE W.R.T.R.	MASK ANGLE		
4/1	8	155 mm	406	2	234.7	14.05 KM	14.0°	0°	MODERATE RAIN FALL	2 FEB 73 AM
4/2	8	4.2"	900	20	216.2	14.05 KM	27.5°	0°	"	"
4/3	8	105 mm	375	1	195.0	14.05 KM	10.0°	0°	"	"
4/4	8	175 mm	236	1	510.5	14.05 KM	2.5°	0°	"	"
5/1	3	105 mm	306	6	365.0	10.44 KM	90.0	1.0°	CLOUDY MILD	30 JAN 73 AM
5/2	3	105 mm	322	6	365.0	10.44 KM	[illegible]	1.0°	"	"
5/3	3	105 mm	285	6	365.0	10.44 KM	2.0°	1.0°	"	"
5/4	3	105 mm	317	1	195.0	10.44 KM	10.0°	1.0°	"	"
5/5	3	105 mm	324	3	231.0	10.44 KM	7.0	1.0°	"	"
6	5	105 mm	282	3	231.0	10.2 KM	86.0°	0°	WINDY LIGHT RAIN	31 JAN 73 AM
7/1	5	105 mm	358	5	301.0	10.44 KM	2.0°	0°	CLOUDY MILD	30 JAN 73 PM
7/2	5	105 mm	232	7	464.0	10.44 KM	7.0°	0°	"	"
7/3	5	105 mm	312	5	301.0	10.44 KM	9.0°	0°	"	"
7/4	5	105 mm	221	7	464.0	10.44 KM	11.0°	0°	"	"
8	10	155 mm	402	4	310.0	10.44 KM	7.0	0°	"	30 JAN 73 PM

TEST # / SEQ #	NUMBER OF ROUNDS	WEAPON				RADAR				
		TYPE	QE MILS	CHARGE	M.V. M/S	RANGE TO WEAPON	INITIAL ASPECT ANGLE W.R.T. R.	MASK ANGLE	WEATHER	
9/1	15	105 mm	371	6	365	11.35 KM	17.5°	0°	WINDY LIGHT RAIN	31 JAN 73 PM
9/2	15	105 mm	356	5	301	10.7 KM	16.5°	0°	"	"
9/3	15	105 mm	276	3	231	8.36 KM	5.5°	0°	"	"
9/4	15	105 mm	417	4	262	9.5 KM	18.0°	0°	"	"
9/5	15	105 mm	297	3	231	8.2 KM	7.0°	0°	"	"
9/6	15	105 mm	264	2	214	7.4 KM	27.0°	0°	"	"
10/1	25	105 mm	462	4	262	9.15 KM	15.0°	0°	SLEET, EXTREME COLD, WINDY	6 FEB 73 AM
10/2	25	105 mm	536	4	262	9.95 KM	21.0°	0°	"	"
11/1	15	105 mm	456	4	262	9.3 KM	10.7°	0.5°	WARM AND SUNNY	7 MARCH 73 PM
11/2	15	105 mm	539	4	262	9.3 KM	17.5°	0.5°	"	"
12/1	15	105 mm	549	4	262	10.65 KM	11.0°	1.0°	WARM SUNNY	7 MARCH 73 AM
12/2	15	105 mm	434	4	262	9.55 KM	19.0°	0.5°	"	"
12/3	15	105 mm	437	5	301	8.8 KM	28.0	0°	"	"

TEST # / CCQ #	NUMBER OF ROUNDS	WEAPON				RADAR				
		TYPE	QE MILS	CHARGE	M.V. M/S	RANGE TO WEAPON	INITIAL ASPECT ANGLE W.R.T. R.	MASK ANGLE	WEATHER	
13/1	6	155 mm	416	6	463.0	11.62 KM	10.0°	0.2°	CLEAR COLD	27 FEB 73 PM
13/2	6	155 mm	458	6	463.0	11.62 KM	17.0°	0.2°	"	"
13/3	6	155 mm	428	6	463.0	11.62 KM	17.0°	0.2°	"	"
13A/1	6	155 mm	305	6	463.0	10.15 KM	21.0°	0°	HEAVY FOG COLD, DAMP	28 FEB 73 PM
13A/2	6	155 mm	349	6	463.0	10.15 KM	21.0°	0°	"	"
13A/3	6	155 mm	331	6	463.0	10.15 KM	22.0°	0°	"	"
14	15								CLOUDY COLD	13 FEB 73 PM-AM
15/1	25	175 mm	501	3	914.4	28.0 KM			CLEAR MILD.	14 FEB 73 AM
15/2	25	175 mm	540	3	914.4	28.0 KM			"	"
15A/1	15	8.0" HOW	546	7	590.0	16.05 KM	10.0°	0°	CLOUDY WINDY COLD	21 FEB 73 PM
15A/2	15	8.0" HOW	618	6	500.0	16.05 KM	11.5°	0°	"	"
16/1	10	8.0" HOW	671	7	590.0	17.1 KM	10.0°	0.5°	HEAVY SNOW COLD	22 FEB 73 PM
16/2	10	8.0" HOW	518	7	590.0	15.4 KM	11.0°	0.5°	"	"
17	15	175 mm	680	2	704.1	5.6 KM	8.0°	0°	WARM SUNNY	6 MARCH AM

Test # / Seq #	Number of Rounds	Weapon: Type	Weapon: QE Mils	Weapon: Charge	Weapon: M.V. M/S	Radar: Range to Weapon	Radar: Initial Aspect Angle W.R.T.R.	Radar: Mask Angle	Weather	
18/1	10	4.2"	900	$19\frac{4}{8}$	212.6	5.4 KM	19.0°	0°	WARM SUNNY	6 MARCH PM
18/2	10	4.2"	900	$19\frac{2}{8}$	210.0	5.4 KM	19.0°	0°	"	"
18/3	10	81 mm	1004	7	230.0	5.4 KM	21.0°	0°	"	"
18/4	10	81 mm	1020	7	230.0	5.4 KM	22.0°	0°	"	"

Test #2 Firing Data

FP-497 23 JAN 73 4.2" MORTAR

TGT	CH	DEF	RANGE	MO	MV	QE	TOF
409	17	2920	2900	1152		900	
442	12 6/8	3042	2200	1152		900	
457	19 2/8	2775	3300	1152		900	
422	13 2/8	2795	2300	1152		900	
435	19	3081	3250	1152		900	

Display of the short range console was degraded to a point that the test could not be started. The most noticeable was the range rings which at first appeared as 400 HZ. Sweep, range strobe, and cursor are out of sync at 90°. Display alignment was performed which cleared up some of the problems. The range rings are still unstable. Generator was checked and found to be operational. After approx. 2 hours the range rings stablized. Possible temperature problem.

RAD AN/TPQ-31 LOCATION ~~6455/4710~~ 6445/4705 DATE 23JAN73 CHARGE ____ QE ____ PROJECTILE 4.2"

TIME	FIRST DETECTION		LAST DETECTION		PREDICTED ORIG		PREDICTED IMPACT		TEST #2 BLIP SCAN FP-497 A=3925 M R=8225 METERS
	AZ MILS	RG KM	AZ MILS	RG KM	AZ	RG	AZ	RG	
	NO USEABLE DATA								
	RADAR PROBLEMS								

Post #2A Firing Data

FP 351 23 JAN 73 4.2" MORTAR

TGT	CH	DEF	RANGE	MO	MV	QE	TOF
383	17	2650	2910			900	28.6
349	20 4/8	2840	3510			900	31.8
395	15 4/8	2768	2660			900	27.2
386	19	2770	3250			900	30.4
327	17 4/8	2808	3000			900	29.1

RADAR AN/TPQ-31 LOCATION ~~6465/1410~~ 6445/14705 ALT 391.5 DATE 23 JAN 73 CHARGE ______ QE 900 $\bar{m}$ PROJECTILE 4.2" mortar

TEST #2A ~~(LOCATE)~~ (CONFIRM) BLIP SCAN

FP-35
A - 3293 mils
R - 13,250 meters

ROUND	TIME	FIRST DETECTION AZ MIL's	FIRST DETECTION RG KM	LAST DETECTION AZ MIL's	LAST DETECTION RG KM	PREDICTED ORIG AZ MIL's	PREDICTED ORIG RG KM	~~PREDICTED IMPACT~~ AZ MIL's	~~PREDICTED IMPACT~~ RG KM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	1621	3310	12.85	3360	11.10	3307	12,925	+14	-320	0	0	0	0	0	0	1	1	1	1	1	1	0	0																	
2		3290	12.80	3400	11.10	3285	12,875	-8	-350	0	0	0	1	1	1	0	0	0	1	0	0	0																		
3		3290	12.90	3355	11.00	3287	12,980	-6	-270	0	0	0	0	0	0	1	1	1	0	0	0	0																		
4		3300	12.80	3385	11.10	3297	12,850	+4	-400	0	0	0	0	0	0	1	1	1	1	0	0	0	1	0	1															
5	1625	3300	12.90	3440	11.80	3295	12,940	+2	-310	0	0	0	0	0	0	1	1	1	1	1	1	0	0																	
6		3310	12.80	3400	11.60	3305	12,880	+12	-370	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0																
7		3340	12.80	3410	11.60	3332	12,850	+39	-400	0	0	0	0	0	0	1	1	1	1	1	0	0	0																	
8		3340	12.80	3400	11.95	3336	12,875	+43	-375	0	0	0	0	0	0	1	1	1	1	1	0	0	0																	
9		3320	12.90	3380	11.85	3316	12,960	+23	-290	0	0	0	0	0	0	1	1	1	1	0	0	0	0																	
10	1632	3325	12.70	3385	11.90	3323	12,740	+30	-510	0	0	0	0	0	0	1	1	1	1	0	0	0	0																	
11		3300	12.80	3345	12.40	3297	12,725	+4	-525	0	0	0	0	0	0	1	1	1	1	1	0	0	0																	
12		3345	13.20	3360	12.30	3345	13,225	+52	-625	0	0	0	0	0	0	1	1	1	1	1	0	0	0																	
13		3300	12.80	3400	12.00	3296	12,840	+3	-380	1	1	1	1	1	0	0	0	0	0	0	0	0	0																	
14		3310	12.80	3430	12.00	3306	12,825	+13	-420	0	0	0	0	0	0	1	1	1	1	1	0	0	0																	
15	1639	3300	12.85	3330	12.40	3298	12,860	+5	-360	0	0	0	0	0	0	1	1	1	1	1	0	0	0																	
16		3325	12.90	3360	12.00	3325	12,925	+32	-500	0	0	0	0	0	0	1	1	1	1	1	1	0	0																	
17		3315	12.90	3340	11.90	3316	12,960	+23	-400	0	0	0	0	0	0	1	1	1	1	1	1	0	0																	
18		3340	12.90	3375	11.90	3338	12,960	+45	-640	0	0	0	0	0	0	1	1	1	1	1	1	0	0																	
19		3330	12.80	3370	11.90	3327	12,850	+34	-580	0	0	0	0	0	0	1	1	1	1	1	0	0	0																	
20	1644	3320	12.80	3400	11.95	3315	12,860	+22	-480	0	0	1	1	1	1	1	1	0	0	0	0	0	0																	
21		3315	12.90	3355	11.40	3313	12,970	+20	-360	0	0	0	0	0	0	1	1	1	0	0	0	0	0																	
22		3320	12.80	3355	12.40	3318	12,825	+25	-500	0	0	0	0	0	0	1	1	1	1	0	0	0	0																	
23		3325	12.85	3400	11.90	3322	12,910	+29	-480	0	0	0	0	0	0	1	1	1	1	1	0	0	0																	
24		3310	12.80	3350	12.40	3307	12,825	+14	-440	0	0	0	0	0	0	1	1	1	1	1	0	0	0																	
25	1651	3310	12.80	3350	12.40	3307	12,850	+14	-420	0	0	0	0	0	0	1	1	1	1	1	1	0	0																	
26																																								
27		AVERAGE		RANGE		ERROR		-426 meters																																
28		AVERAGE		AZIMUTH		ERROR		19.9 mils																																
29		BLIP		SCAN		RATIO		49%																																
30																																								
31																																								

RADAR WAS RE-ORIENTED TO MAKE UP FOR THE 120 METER RANGE GATES. SWEEP WAS MOVED 60 MILS EAST TO COMPENSATE FOR THE AZIMUTH ERROR.

Test #2B Firing Data

FP-170 24 JAN 73 4.2" MORTAR

TGT	CH	DEF	RANGE	MO	MV	QE	TOF
25	14 4/8	2907	2500			900	26
17	16	3075	2700			900	27
11	17 4/8	3250	2960			900	29
28	19 4/8	2982	3350			900	31
62	19	2805	3250			900	30

Shorting wire to antenna pedestal located in Power distribution panel burnt out. Overload in pedestal occured.

RADAR AN/TPQ-31 LOCATION ~~6445/4705~~ 3312/4244 DATE 24 JAN 78 CHARGE ______ QE ______ PROJECTILE 4.2"

FIRST DETECTION		LAST DETECTION		PREDICTED ORIG		PREDICTED IMPACT		TEST #-2B BLIP SCAN FP-17D A-1280 R-4450 METERS
AZ MILS	RG KM	AZ MILS	RG KM	AZ	RG	AZ	RG	
NO USEABLE DATA								
RADAR PROBLEMS								

TEST #3 Firing Data

FP-524 24 JAN 73 4.2" MORTAR

TGT	CH	DEF	RANGE	MO	MV	QE	TOF
364	13 4/8	2896	2300 ~~3440~~			900	25
322	15 1/8	3038	2650 ~~3420~~			900	27
319	20 4/8	2946	3480			900	32
327	20 1/8	2840	3500			900	32
6346/3648	16	2759	2790			900	28

Short range console display was instable. Sweep, range strobe, range marks, and cursor are out of ~~alignment and~~ sync.

(AN/TPQ-3) LOCATION ~~4445/4716~~ 6445/4705 DATE 24JAN73 CHARGE ____ QE ____ PROJECTILE 4.2"

T I M E	FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIGIN AZ MILS	PREDICTED ORIGIN RG KM	PREDICTED IMPACT AZ MILS	PREDICTED IMPACT RG KM	TEST #3 BLIP SCAN FP-524 A-3233M R-13,400 METERS
	NO USEABLE DATA								
	RADAR PROBLEMS								

Test #3A Firing Data

FP-415 (30m EAST) 26 JAN 73 4.2" Mortar

TGT	CH	DEF	RANGE	MO	MV	QE	TOF
426	12	3003	2040			900	24
405	18 4/8	2991	3180			900	30
453	16	2863	2730			900	28
430	19 4/8	2707	3310			900	31
439	16	2675	2700			900	28

[illegible] AN/TPQ-31 LOCATION ~~6466 4710~~ 6445/4705 DATE 26 Jan 73 CHARGE . QE 900 mils PROJECTILE 4.2" Mortar

BLIP SCAN Test 3A (LOCATE)

ROUND	TIME	FIRST DETECTION AZ MIL'S	FIRST DETECTION RG KM	LAST DETECTION AZ MIL'S	LAST DETECTION RG KM	PREDICTED ORIG AZ MIL'S	PREDICTED ORIG RG KM	PREDICTED IMPACT AZ MIL'S	PREDICTED IMPACT RG KM
1	1255	3370	7.8	3427	6.7	3355	8.0	6345	3915
2	+	3390	8.3	3490	6.3	3383	8.55	6315	3875
3		3420	7.5	3526	6.5	3410	7.7	6310	3955
4	+	3400	7.6	3500	6.3	3390	7.8	6325	3945
5		NOT SEEN							
6	x	3360	8.2	3650	5.4	3342	8.6	6350	3860
7		3440	7.4	3580	5.5	3425	7.7	6300	3955
8	^	3430	7.4	3590	5.4	3420	7.65	6305	3920
9		3390	7.8	3600	5.4	3375	8.15	6330	3925
10	+	3390	7.7	3600	5.5	3373	8.00	6335	3915
11	x	3370	7.4	3500	5.4	3350	7.7	6350	3945
12	+	3400	7.5	3490	5.5	3395	7.7	6320	3950
13	+	3400	7.4	3500	5.6	3395	7.6	6325	3965
14		3400	7.7	3530	5.4	3393	7.9	6320	3925
15		3370	7.4	3500	5.6	3385	7.6	6330	3960
16	+	3380	7.6	3500	4.6	3373	8.0	6345	3925
17		3390	7.3	3490	4.5	3382	7.6	6335	3960
18	x	3390	7.4	3500	4.5	3387	7.7	6325	3950
19		3400	7.5	3510	4.8	3395	7.8	6320	3940
20		3400	7.8	3500	4.8	3395	8.1	6315	3915
21	x	3300	7.8	3460	5.2	3293	8.0	6395	3905
22	x	3360	7.7	3430	5.6	3335	7.9	6350	3930
23		3390	7.5	3430	5.5	3390	7.7	6325	3950
24	x	3360	7.6	3430	5.4	3355	7.8	6345	3935
25	+	3350	7.6	3420	5.4	3345	7.8	6355	3935
26									
27		FP-415							
28		A-3350							
29		R-8.150							
30		Blip Scan 95.4%							
31									
32									
33									
34									
35									
36									

ROUND	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	/	/	/	/	/	/	/																								
2	/	/	/	/	/	/	/	/	/																						
3	/	/	/	/	/	/	0	/	/																						
4	/	/	/	/	/	/	/	0	/	/																					
5																															
6	/	/	/	/	/	/	/	/	/																						
7	/	/	/	/	/	/	/	/	/																						
8	/	/	/	/	/	/	/	/	/																						
9	/	/	/	/	/	/	/	0	/																						
10	/	/	/	/	/	/	/	/	/																						
11	/	/	/	/	/	/	/	0	/	/																					
12	/	/	/	/	/	/	/	/	/	0	/	/																			
13	/	/	/	/	/	/	/	/	/	/	/																				
14	/	/	/	/	/	/	/	/	/	0	/	/																			
15	/	/	/	/	/	/	/	/	/	/	/	/																			
16	/	/	/	/	/	/	/	/	/	/	/																				
17	/	/	/	/	/	/	/	/	/	/	/																				
18	/	/	/	/	/	/	/	/	/	/	/	/																			
19	/	/	/	/	/	/	/	/	/	/	/	0	/																		
20	/	/	/	/	/	/	/	/	/	/	0	0	/																		
21	/	/	/	/	/	/	/	/	/	/	/	0	/																		
22	/	/	/	/	/	/	/	/	/	/	0	/	/																		
23	/	/	/	/	/	/	/	/	/	/	/	0	/																		
24	/	/	/	/	/	/	/	/	/	/	/	/	0	/																	
25	/	/	/	/	/	/	/	/	/	0	/	/	/	/																	

F-5-17

Test # 3B Firing Data

FP-174 (200 meters West) 24 JAN 73 4.2" MORTAR

TGT	CH	DEF	RANGE	Azmo	MV	QE	TOF
11	22	2802	3800	25°		900	33
17	21 4/8	2669	3690	17.5°		900	33
4771/5767	24	2653	4170	[redacted] 4°		900	35
9	22 4/8	2710	3860	20.5		900	34
20	22 4/8	2647	3890	16.0		900	34

MASK → 0°

RADAR AN/TPQ-3/ LOCATION ~~6466/4710~~ 6445/4705 DATE 24 Jan 73 CHARGE ______ QE 900ф PROJECTILE 4.2" mortar

BLIP SCAN Test 3B Rae.

ROUND	TIME	FIRST DETECTION AZ MIL'S	FIRST DETECTION RG KM	LAST DETECTION AZ MIL'S	LAST DETECTION RG KM	PREDICTED ORIG AZ MIL'S	PREDICTED ORIG RG KM	PREDICTED IMPACT AZ MIL'S	PREDICTED IMPACT RG KM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1		4260	22.3	4340	21.2	4235	22.7	4530	3520	1	1	1	1																											
2																																								
3																																								
4																																								
5																																								
6	1330	4350	22.3	4250	21.4	4250	22.6	4530	3550	1	1	1																												
7		4340	22.3	4250	21.4	4235	22.6	4545	3525	1	1	1																												
8		4240	22.3	4250	21.5	4235	22.6	4545	3525	1	1	1																												
9		4230	22.4	4250	21.5	4225	22.5	4550	3500	1	1	1																												
10		4242	22.2	4250	21.1	4240	22.5	4545	3525	1	1	1	1																											
11		4265	22.3	4230	20.1	4225	22.5	4545	3590	1	0	1	1	1																										
12																																								
13																																								
14																																								
15																																								
16		4250	22.3	4285	21.1	4245	22.6	4540	3535	1	1	1	1																											
17		4260	22.2	4250	21.3	4260	22.4	4580	3580	1	1	1	1																											
18		4240	22.3	4260	21.4	4225	22.5	4555	3525	1	1	1	1																											
19		4235	22.2	4220	20.4	4240	22.5	4550	3530	1	1	1	1	1	0	1																								
20		4235	22.2	4220	20.4	4228	22.4	4555	3515	1	1	0	1	1																										
21		4260	22.2	4245	21.2	4260	22.4	4580	3560	1	0	1	1																											
22		4165	22.3	4255	21.3	4139	22.7	4655	3335	1	1	1																												
23		4255	22.0	4270	21.3	4252	22.3	4569	3570	1	0	1	1	1																										
24		4235	22.2	4260	21.3	4230	22.5	4565	3519	1	1	1																												
25	1350	4260	22.2	4260	21.3	4259	22.5	4530	3570	1	1	1																												
26																																								
27		FP 148																																						
28		A-4247																																						
29		R-22.7																																						
30		AVERAGE		RANGE ERROR - 456 METERS																																				
31		"		AZIMUTH		" - 17 MILS																																		
32		BLIP SCAN RATIO				- 92%																																		
33																																								
34																																								
35																																								
36																																								

F-5-19

Test #4 Firing Data

FF-335 2 FEB 73 WEAPON CLASSIFICATION TEST

WEAPON	TGT	CH	DEF	RANGE	DO	MV	QE	TOF
155	307	2	2645	3640			406	18
4.2"	320	20	3110	3420			900	31
105	309	1	3374	2160			375	15
175	422	1	3234	8080			236	22

Main circuit breaker tripped. Visual inspection showed antenna control CB tripped. No other unusual symptoms in static condition. Reapplied power. With antenna turning an unusually large amount of current was drawn on the Ø3 input. System will not time out after 15 minutes. Inspection of the antenna pedestal showed oil leakage around synchros and terminal board. Suspect oil ~~soak~~ soaked drive motor and terminal board. Radar removed from the field.

RADAR AN/TPQ-31 LOCATION 6445/4705 DATE 2 FEB 73 CHARGE ______ QE ______ PROFILE ______

ROUND	TIME	FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIG AZ	PREDICTED ORIG RG	PREDICTED IMPACT AZ	PREDICTED IMPACT RG	BLIP SCAN TEST 4
1										
2										
3		RADAR WAS DOWN FOR PROBLEMS								
4		UNKNOWN. NO USEABLE DATA								
5		WAS COLLECTED								
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										

Test #5 Firing Station

FP-300 30 JAN 73 105mm

TGT	CH	DFF	RANGE	MO	MV	QE	TOF
424	6	3140	6060	Sey 5		306	21
450	6	3203	6280	Sey 4		322	22
410	6	3295	5750	Sey 3		285	20
307	1	1817	2330	Sey 2		317	12
319	3	1708	3350	Sey 1		324	15

RADAR AN/TPQ-31 LOCATION ~~6465 4710~~ 6445/4705 DATE 30 JAN 73 CHARGE ____ Q.E ____ PROJECTILE 105mm

FP 300
A-3753
R-10,650

BLIP SCAN TEST #5

ROUND	TIME	FIRST DETECTION AZ MLS	FIRST DETECTION RG KM	LAST DETECTION AZ MLS	LAST DETECTION RG KM	PREDICTED ORIG AZ MLS	PREDICTED ORIG RG KM	PREDICTED IMPACT AZ MLS	PREDICTED IMPACT RG KM
1	11 14	3600	10.5	3505	10.9	3620	10.5		
2	11 15	3610	10.5	3500	11.2	3645	10.35		
3	11 16	3620	10.4	[illegible]	11.0	3640	10.35		
4	11 19	NOT		SEEN					
5	11 20	"		"					
6	11 21	"		"					
7	13 34	3700	8.1	3710	4.3	3700	8.8		
8	13 35	3680	8.1	3700	4.5	3680	8.85		
9	13 36	3720	7.8	3720	4.4	3725	9.0		
10	13 37	3710	9.4	3620	3.6	3710	9.95		
11	13 38	3630	9.8	3620	3.8	3630	10.36		
12	13 39	3680	8.2	3610	3.8	3690	8.65		
13	13 40	3725	9.8	3500	4.4	3796	10.49		
14	13 41	3710	10.0	3580	4.2	3716	10.77		
15	13 42	3640	8.3	3520	4.4	3646	8.8		
16		AVERAGE		RANGE		ERROR		1383 meters	
17		AVERAGE		AZIMUTH		ERROR		75.3 m	
18		BLIP		SCAN		RATIO		81%	
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									
33									
34									
35									
36									

CONFIRM

ROUND	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	1	1	1	1	1	1	0	0	0	0	0	0	0																		
2	1	1	1	1	1	0	0	0	0	0	0	0	0																		
3	1	1	1	1	1	1	1	0	0	0	0	0	0																		
4	NOT				SEEN																										
5		"				"																									
6		"				"																									
7	0	0	1	1	1	1	0	1	1	0	0	0	0																		
8	0	0	1	1	1	1	0	1	1	0	0	0	0																		
9	0	0	1	1	0	0	1	1	0	0	0	0	0																		
10	0	1	1	1	1	1	1	1	1	1	1	1	1	0																	
11	0	1	1	1	1	1	1	1	1	1	1	1	1	0																	
12	0	1	1	1	1	1	1	1	1	1	1	1	0	0																	
13	0	1	1	1	1	1	1	1	1	1	0	0	0	0																	
14	0	1	1	1	1	1	1	1	1	1	0	0	0	0																	
15	0	1	1	1	1	1	1	1	1	1	0	0	0	0																	

Test # 6 Firing Data

FP-380 31 JAN 73 105mm

TGT	C.H	DEF	RANGE	MO	MV	QE	TOF
309	3	3039	3000			282	14

RADAR AN/TPQ-31 LOCATION ~~6465/4710~~ 6415/4305 DATE 31 JAN 73 CHARGE 3 QE 282 PROJECTILE 105mm

ROUND	TIME	FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIG AZ	PREDICTED ORIG RG	PREDICTED IMPACT AZ	PREDICTED IMPACT RG	TEST #6 BLIP SCAN FP-380 Q-3747 ft R-10,250 meters
1										
2										
3										
4										
5										
6		NO USEABLE DATA								
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										
36										

Test #7 Firing Data

FP-300 30 JAN 73 105mm

TGT	CH	DEF	RANGE	HIO	DIV	QE	TOF
410	5	3294	5740			358	21
450	7	3202	6270			232	19
405	5	3171	5180			312	19
424	7	3144	6070			221	18

RADAR AN/TPQ-31 LOCATION ~~6465 4710~~ 6445/4705 DATE 30JAN'73 CHARGE . QE ___ PROJECTILE 105mm

Test #7

ROUND	TIME	FIRST DETECTION		LAST DETECTION		PREDICTED ORIG.		PREDICTED IMPACT		FP-300 A-3763 R-10,650 BLIP SCAN																														
		AZ MIL's	RG KM	AZ MIL's	RG KM	AZ MIL's	RG KM	AZ MIL's	RG KM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	1420	3725	9.4	3675	4.6	3731	10.0			0	0	0	1	1	1	1	1	1	1	1	1	0	0																	
2		3690	7.4	3680	4.6	3699	8.1			0	0	0	0	1	1	1	1	1	0	0	0	0	0																	
3		3730	9.3	3730	4.8	3730	10.1			0	1	0	0	1	1	1	1	1	1	0	0	0	0																	
4		3790	10.5	3690	4.6	3795	11.4			0	1	0	0	1	1	1	1	0	1	1	0	0	0																	
5		3710	9.9	3720	4.6	3710	10.5			0	0	0	0	1	1	1	1	1	1	1	1	0	0																	
6		3790	10.3	3560	4.3	3750	11.3			0	1	0	0	1	1	1	1	1	1	0	0	0	0																	
7		3675	7.5	3560	4.4	3687	8.1			0	1	0	0	1	1	1	1	1	1	1	0	0	0																	
8		3740	10.4	3590	5.4	3799	10.9			0	1	0	0	1	1	1	1	1	1	1	0	0	0																	
9		3735	10.1	3575	4.2	3740	10.6			0	0	1	1	1	1	1	1	1	1	1	1	1	1	0																
10		3715	9.5	3520	4.2	3724	10.0			0	0	1	1	1	1	1	1	1	1	1	1	1	1	0																
11		3640	7.5	3690	5.2	3639	7.9			0	0	0	0	0	1	1	1	1	1	1	1	0	0	0																
12		3665	8.9	3560	5.4	3675	9.4			0	0	1	0	1	1	1	1	1	1	1	1	0	0	0																
13		3700	10.6	3560	5.6	3705	11.1			1	1	0	1	1	1	1	1	1	1	1	1	0	0	0																
14		3700	10.5	3560	5.5	3705	10.9			1	0	1	1	1	1	1	1	1	1	1	1	1	0	0																
15		3730	10.1	3640	5.1	3735	10.5			1	0	1	1	1	1	1	1	1	1	1	1	1	0	0																
16		3710	7.5	3575	4.4	3723	7.9			0	0	0	0	1	1	1	1	1	1	1	1	1	0	0																
17		3750	9.6	3600	4.2	[illegible]	10.15			1	1	0	1	1	1	1	1	1	1	1	1	0	0	0																
18		3680	7.4	3635	4.1	[illegible]	7.85			0	0	0	0	1	1	1	1	1	0	1	1	1	0	0																
19		3750	9.3	3585	4.3	3756	9.75			1	0	1	1	1	1	1	1	1	1	1	1	1	0	0																
20	1420	3750	9.5	3570	4.3	3775	10.0			1	0	0	1	1	1	1	1	1	1	1	1	1	0	0																
21																																								
22		AVERAGE		RANGE		ERROR		1030 METERS																																
23		AVERAGE		AZIMUTH		ERROR		29.6 m																																
24		BLIP		SCAN		RATIO		64%																																
25																																								
26		OPERATORS WERE HAVING TROUBLE																																						
27		DISTINGUISHING ROUNDS DUE TO																																						
28		NUMEROUS ARTILLERY FIRINGS																																						
29		IN THE AREA OF THE RADAR.																																						
30																																								
31																																								
32																																								
33																																								
34																																								
35																																								
36																																								

Test #8 Firing Data

FP-300 30 JAN 73 155mm

TGT	CH	DEF	RANGE	MO	MV	QE	TOF
437	4	3000	5860			40.2	22.9

RANGE ~~FB'TP2-3~~ LOCATION ~~6465 4710~~ 6445/4705 DATE 30 JAN 73 CHARGE 4 QE 402 PROJECTILE 155mm

FP 300
A - 3753
R - 10,650

BLIP SCAN (CONFIRM) TEST # 8

ROUND	TIME	FIRST DETECTION AZ MIL'S	FIRST DETECTION RG KM	LAST DETECTION AZ MIL'S	LAST DETECTION RG KM	PREDICTED ORIG AZ MIL'S	PREDICTED ORIG RG KM	PREDICTED IMPACT AZ MIL'S	PREDICTED IMPACT RG KM
1	1440	3750	10.6	3650	4.5	3753	11.1		
2	1441	3730	9.9	3650	4.7	3731	10.3		
3	1442	3730	8.0	3640	4.5	[illegible]	8.4		
4	1443	3750	9.9	3650	4.5	3755	[illegible]		
5	1444	3740	8.4	3675	4.4	3745	8.9		
6	1445	3770	10.1	3650	4.5	3775	10.65		
7	1446	3750	10.6	3650	4.4	3755	11.19		
8	1447	3730	3.2	3630	4.4	3735	8.6		
9	1448	3710	8.0	3650	4.5	3715	[illegible]		
10	1449	3755	10.6	3650	4.4	3760	11.2		
11									
12		AVERAGE		RANGE		ERROR		966 METERS	
13		AVERAGE		AZIMUTH		ERROR		13.3 mils	
14		BLIP		SCAN		RATIO		7890	
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									
33									
34									
35									
36									

ROUND	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	1	1	0	0	1	1	1	1	1	1	1	1	1	1																	
2	1	1	0	0	1	1	1	1	1	1	1	1	1	1																	
3	0	0	0	1	1	1	1	1	1	1	1	1	1	1																	
4	1	0	0	1	1	1	1	1	1	1	1	1	1	0																	
5	0	0	1	1	1	1	1	1	1	1	1	1	1	0																	
6	1	1	0	0	1	1	1	1	1	1	1	1	1	0																	
7	1	1	0	0	1	1	1	1	1	1	1	1	1	0																	
8	0	0	0	1	1	1	1	1	1	1	1	1	1	0																	
9	0	0	0	0	1	1	1	1	1	1	1	1	1	0																	
10	1	1	0	0	1	1	1	1	1	1	1	1	1	0																	

Test #9 Firing Data

ALL ROUNDS TO TGT # 426 31 JAN 73 105mm

SEQ #	FP	CH	DEF	RANGE	A→MD	MV	QE	TOF
1	347	6	2758	6590	17.5°	332	371	24
2	303	5	3161	5710	16.5°	371M	356	21
3	387	4	2776	4450	18.0°	330	417	21
4	416	3	3203	2960	5.5°	330	276	13
5	422	3	2752	2800	7.0°	NO DATA	297	13
6	421	2	3500	2430	26°	330	264	12

Firing Points for Sequences 3 and 4 above are reversed. Therefore, accompanying data sheets, Sequence 3 and 4, refer to firing points 416 and 387 respectively.

RADAR AN/TPQ-31 LOCATION ~~6464~~ 6445/4705 DATE 31 Jan '73 CHARGE ______ QE ______ PROJECTILE 105mm

BLIP SCAN (LOCATE) Test #9 SEQUENCE #I

ROUND	TIME	FIRST DETECTION AZ MLS	FIRST DETECTION RG KM	LAST DETECTION AZ MLS	LAST DETECTION RG KM	PREDICTED ORIG AZ MLS	PREDICTED ORIG RG KM	PREDICTED IMPACT AZ MLS	PREDICTED IMPACT RG KM	1	2	3	4	5	6	7	8	9	10	11	12–27
1	1132	3880	8.2	3820	6.3	3885	8.6	6930	4025	1	1	1	1	1	0	1	1	1	0	0	
2	1133	3760	8.4	3760	5.5	3760	8.7	-		1	1	1	1	1	0	1	0	0	0	0	
3	1134	3720	8.1	3660	6.6	3734	8.4			1	1	1	1	1	0	0	1	0	0	0	
4	1135	3720	8.2	3710	7.2	3725	8.4			1	1	1	1	0	1	0	0	0	0	0	
5	1136	3730	8.2	3660	6.6	3740	8.5			1	1	1	0	0	1	0	0	0	0	0	
6	1137	3540	8.3	3550	5.7	3530	8.5			1	1	1	0	1	1	1	0	0	0	0	TRACKED WRONG ROUND
7	1138	3720	8.2	3700	6.6	3722	8.5			1	1	1	1	0	1	1	0	0	0	0	
8	1139	3750	8.3	3710	6.4	3753	8.6			1	1	1	1	0	1	1	0	0	0	0	
9	1140	3750	8.3	3700	6.9	3760	8.5			1	1	1	1	1	0	1	1	0	0	0	
10	1141	3750	8.3	3730	6.6	3751	8.5			1	1	1	1	1	0	0	1	0	0	0	
11	1142	3730	8.2	3740	6.4	3730	8.7			1	1	1	1	1	1	0	1	0	0	0	
12	1143	3730	8.1	3650	6.6	3745	8.5			1	1	1	1	0	0	1	0	0	0	0	
13	1144	3750	8.2	3680	6.8	3761	8.5			1	1	1	1	0	0	1	0	0	0	0	
14	1145	3750	8.3	3630	6.4	3766	8.3			1	1	1	1	0	0	1	0	0	0	0	
15	1146	3700	8.1	3680	6.8	3705	8.4			1	1	1	1	0	0	1	0	0	0	0	
16																					
17																					
18																					
19		FP-400																			
20		A-3738																			
21		R-8650																			
22		6035 3960																			
23		BLIP SCAN		RATIO 64%																	
24																					
25		AVERAGE		RANGE		ERROR		269 meters													
26		AVERAGE		AZIMUTH		ERROR		28 mils													
27																					
28																					

F-5-31

RADAR AN/TPQ-31 LOCATION [illegible] DATE 31 JAN 73 CHARGE ______ Q.E. ______ PROJECTILE 105 MM

ROUND	TIME	FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIG AZ MILS	PREDICTED ORIG RG KM	PREDICTED IMPACT AZ MILS	PREDICTED IMPACT RG KM	BLIP SCAN (LOCATE) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	1323	3730	8.4	3550	5.5	3746	8.4	6040	3985	1	1	0	1	1	1	0	1	1	1																					
2	[illegible]	3750	9.0	3560	5.5	3161	9.4			1	1	1	1	1	0	1	1	1	1																					
3	1325	3750	9.0	3550	5.6	3764	9.5			1	1	1	1	1	0	0	1	1	1																					
4	1326	3750	9.0	3556	5.7	3769	9.4			1	1	1	1	0	1	1	1	1	1																					
5	1327	3730	8.2	3580	5.4	3746	8.7			0	0	0	1	0	1	1	1	1	1																					
6	1328	3730	8.8	3550	5.6	3742	9.1			1	1	1	1	1	0	0	1	1	1																					
7	1329	3760	8.8	3550	5.5	3778	9.4			1	1	1	1	0	1	0	1	1	1																					
8	1330	3750	9.4	3540	5.5	3765	9.9			1	1	1	1	0	1	1	1	H	1																					
9	1331	3720	8.1	355[illegible]	5.5	3736	8.5			1	1	1	1	0	1	1	1	0	0																					
10	1332	3770	10.1	3550	5.5	3792	11.1			1	1	1	0	0	1	0	0	1	1																					
11	1333	3700	8.7	3550	5.3	3714	9.1			1	1	1	0	0	1	1	1	1	1																					
12	1334	3730	9.1	3560	5.5	3747	9.7			1	1	1	1	0	0	1	0	1	1																					
13	1335	3720	8.9	3560	5.6	3735	9.4			1	1	1	1	1	0	0	1	1	0																					
14	1336	3720	8.9	3580	5.3	3730	9.4			1	1	1	1	1	0	0	1	1	1																					
15	1337	3700	8.2	3550	5.1	3787	8.6			1	1	1	1	1	0	0	1	1	1																					

19 EP 370

20 A-3768

21 R-9.65

23 GRID 5980 · 1390

24 BLIP SCAN RATIO 77%

26 AVERAGE RANGE ERROR 6.39 METERS

27 AVERAGE AZIMUTH ERROR 19.6 m

RADAR AN/TPQ-31 LOCATION ________ DATE 3 JAN '73 CHARGE ________ QE ________ PROJECTILE 105mm

ROUND	TIME	FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIG AZ	PREDICTED ORIG RG	PREDICTED IMPACT AZ	PREDICTED IMPACT RG	BLIP SCAN									
1	1503	3530	7.7	3500	5.4	3542	8.15	6200	3940	1	1	1	0	1	1	0	1	1	
2	1504	IMPACT		3520	5.2	———													
3	1505	3600	8.2	3590	5.8	3604	8.9			0	1	1	0	0	1	1	1		
4	1506	3590	7.6	3590	5.7	3595	8.2			1	0	[illegible]	1	0	1	1			
5	1507	3610	7.6	3600	5.5	3617	8.4			1	0	1	1	1	1	1	1	1	
6	1508	3600	7.6	3600	5.5	3601	8.0			1	0	0	1	1	0	1	1	1	
7	1509	3600	8.3	3530	5.1	3605	8.7			1	1	1	1	0	1	1	1	1	
8	1500	3570	7.6	3590	5.6	3594	7.82			1	1	1	1	0	1	1	1	1	
9	1511	3590	8.3	3550	5.5	3596	8.7			1	1	1	1	0	1	1	1	1	
10	1512	3550	8.2	3550	5.4	3550	8.75			1	1	1	1	0	1	1	1	1	
11	1513	3560	7.6	3530	5.4	3552	7.98			1	1	1	1	0	1	1	0		
12	1514	3560	8.2	3530	4.6	3565	8.75			1	1	1	1	1	1	1	1		
13	1515	3560	8.2	3520	5.6	3573	8.3			1	1	1	0	1	0	0	0		
14	1516	3570	8.3	3530	5.6	3570	8.9			1	1	1	0	1	0	0	0		
15	1517	3540	8.2	3530	5.6	3545	8.35			1	1	1	0	1	0	0	0		
16																			
17	F-5-33																		
18																			
19		FP-405																	
20		A-3570																	
21		R-8550																	
22		6165-3905																	
23		BLIP SCAN RATIO				77%													
24																			
25		AVERAGE		RANGE		ERROR		398 METERS											
26		AVERAGE		AZIMUTH		ERROR		21.9 ℳ											
27																			
28																			
29																			
30																			
31																			
32																			
33																			
34																			

RADAR AN/TPQ-21 LOCATION ______ DATE 31 Jan 73 CHARGE ______ QE ______ PROJECTILE 105mm

TEST #9 SEQ #4

ROUND	TIME	FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIG AZ MILS	PREDICTED ORIG RG KM	PREDICTED IMPACT AZ MILS	PREDICTED IMPACT RG KM	BLIP SCAN – LOCATE (scans 1–28)
1	1430	3550	6.9	3350	4.1	3572	7.39			1 1 1 1 0 0 1 1 1
2	1431	3680	9.0	3380	4.2	3700	8.5			1 1 1 1 1 0 0 0 1 1 1 0 0
3	1432	IMPACT		3520	5.5					1 1 0 0
4	1433	ONLY		3520	5.2					1 1 0 0
5	1434			3520	5.7					1 1 1 0
6	1435			3500	5.6					1 1 0 0
7	1436			3500	5.5					1 1 0 0
8	1437			3482	5.4					1 1 1 0
9	1438			3510	5.6					1 1 1 0
10	1439			3460	5.7					1 1 0 0
11	1440			3500	5.6					1 1 1 0
12	1441			3500	5.7					1 1 1 0
13	1442			3510	5.6					1 1 1 0
14	1443			3500	5.6					1 1 0 0
15	1444			3500	5.6					1 1 0 0
16										
17		FP 400								
18		A-3736								
19		R-8.65								
20										
21		FIRING POINT WAS DETERMINED								
22		FROM 2 ROUNDS USING RESULTANT								
23		GUN TARGET LINE. ROUND 3-15								
24		WERE NOT SEEN EXCEPT FOR IMPACT								
25										
26										
27										
28										
29										
30										
31										
32										
33										

F-5-34

TEST#9
SEQ#5

TEST FIRING RESULTS

Radar AN/TPQ-31 Location 6465/4712 Date 31 JAN 73

Round	Time	1st Det		Last Det		Predicted Origin		Target Track																			
		R	Az	R	Az	R	Az	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

NO USEABLE DATA

RADAR AN/TPQ-31 LOCATION ________ DATE 31 JAN 73 CHARGE ________ QE ______ PROJECTILE 105 mm

ROUND	TIME	FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIG AZ	PREDICTED ORIG RG	PREDICTED IMPACT AZ	PREDICTED IMPACT RG	BLIP SCAN
1	16[illegible]	IMPACT				3520	5.6			
2						3580	5.6			
3		ONLY				3500	5.6			NO USEABLE
4						3490	5.6			
5						3490	5.6			DATA
6						3520	5.5			
7						3490	5.6			
8						3520	5.6			
9						3570	5.6			
10						3500	5.5			
11						3510	5.4			
12						3520	5.5			
13						3490	5.5			
14	16[illegible]					3510	5.5			
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										

F-5-36

Sheet #10 Firing Data

FF-116 6 FEB. 73 105 mm

SEQ#	TGT	CH	DEF	RANGE	MO	MV	QE	TOF
1	140	4	3232	5300			462	24
2	167	4	3140	3760			536	27

RADAR AN/TPQ-31 LOCATION EP 181 4216/3343 DATE 6 Feb 73 CHARGE 4 QE 462 PROJECTILE 105mm

TEST #10 SEQ #1

ROUND	TIME	FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIG AZ	PREDICTED ORIG RG	PREDICTED IMPACT AZ	PREDICTED IMPACT RG	BLIP SCAN 1	2	3	4	5	6	7	8	9
1	1435	1190	9.1	1130	7.0	1200	9.5	1130		1	1	1	0	1	1	1	1	
2		1180	9.1	1130	7.0	1190	9.6			1	1	1	0	1	1	1	1	
3		NOT SEEN																
4		NOT SEEN																
5		1205	9.6	1100	7.0	1210	10.0			1	1	1	0	1	1	1	1	
6		1210	9.1	1100	6.8	1212	9.55			1	1	1	0	1	1	1	1	
7		1200	8.9	1170	7.4	1205	9.2			1	1	1	0	1	1	1		
8		NOT SEEN								[illegible]	[illegible]		[illegible]					
9		1140	8.9	1100	7.2	1150	9.2			1	1	1	1	1	1	0	1	
10		1190	10.1	1040	7.2	1210	10.6			1	1	1	1	1	1	0	1	
11		1140	9.1	1100	7.2	1145	9.5			1	1	1	0	1	1	0	0	
12		1200	9.7	1050	6.7	1220	10.25			1	1	1	0	1	1	1		
13		1110	8.6	1040	6.6	1120	9.0			1	1	1	0	1	1	0	0	
14		1130	8.3	1110	7.3	1135	8.6			1	1	1	0	1	1	0	0	
15		1140	9.4	1060	6.8	1150	9.9			1	1	1	0	1	1	1		
16		1130	9.2	1040	6.8	1145	9.65			1	1	1	0	1	1	1		
17		1160	8.9	1060	6.5	1175	9.1			1	1	1	1	1	1	1		
18		1140	9.4	1090	7.4	1150	9.9			1	1	1	1	1	1	1		
19		1130	9.2	1080	7.2	1140	9.7			1	1	1	1	1	1	1		
20		1150	9.4	1050	7.0	1175	9.9			1	1	1	0	1	1	1		
21		1190	9.5	1056	6.8	1205	10.0			1	1	1	0	1	0	0		
22		MISFIRE																
23		MISFIRE																
24		1190	9.0	1030	6.5	1210	10.1			1	1	1	1	1	1			
25		1110	9.2	1020	6.8	1125	9.7			1	1	1	1	1	1			
26		1160	9.5	1040	7.0	1175	10.3			1	1	1	1	1	1			
27		1100	8.6	1040	6.5	1110	9.1			1	1	1	1	1	1	1		
28																		
29		FP-116																
30		A-1184																
31		R-9575																
32																		
33		AVERAGE		RANGE		ERROR		192 METERS										
34		AVERAGE		AZIMUTH		ERROR		10 mils										
35		BLIP		SCAN		RATIO		86%										

RADAR AN/TPQ-31 LOCATION FP 181 DATE 6 FEB 73 CHARGE 4 QE 462 PROJECTILE 105mm

BLIP SCAN TEST #10 SEQ #2

NO USEABLE DATA

ROUND	TIME	FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIG AZ	PREDICTED ORIG RG	PREDICTED [illegible] AZ	PREDICTED [illegible] RG	BLIP SCAN
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										
36										

Test #11 Firing Data

FP-111 7 MAR 73 105mm

SEQ #	TGT	CH	DEF	RANGE	FP. PAD MO.	MV	QE	TOF
1	165	4	4900	5260	9400		456	23
2	170	4	5067	5750	9400		539	28

MASK ANGLE = 0.5°

Seg 1 MISS DISTANT =

Seg 2 MISS DISTANT =

SPS AN/TPQ-31 LOCATION ~~3313/4244~~ 4216/3343 DATE 7MAR73 CHARGE 4 QE 456 339 PROJECTILE 105mm

TEST #11
SEQ #1 + #2 BLIP SCAN FP-111 A-1358m R-9325 meters

FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ	LAST DETECTION RG	PREDICTED ORIG AZ	PREDICTED ORIG RG	PREDICTED IMPACT AZ	PREDICTED IMPACT RG	BLIP SCAN	REMARKS
SEQ #1									
1070	9.1	0905	6.5						TRACKED WRONG ROUND
NOT	SEEN								
"	"								
"	"								
1350	89	1070	4.9	358	9140	Ø	-900	1 0 1 1 0 0 0 0 0 0 1	CLUTTER ATTN — OUT
1390	8.9	1060	4.7	1397	9120	+39	-530	1 0 0 1 1 0 0 0 0 1 1	
1310	8.5	1020	5.1	1322	8750	-36	-1280	1 0 0 0 0 0 0 0 0 0 1	RANGE ERROR 983m
1320	8.4	1030	4.3	1329	8640	-29	-690	1 1 0 0 0 0 0 0 0 0 1	
IMPACT		ONLY							AZIMUTH ERROR 25.6m
1300	8.1	1050	4.8	1308	8270	-50	-1110	1 0 0 0 0 0 0 0 0 0 1	
1340	8.2	1070	4.9	1347	8360	-9	-960	1 1 1 0 0 0 0 0 0 1 1	BLIP SCAN RATIO 35%
1320	8.4	1050	4.7	1329	8610	-29	-730	1 0 0 0 0 0 0 0 0 0 1	
1300	7.7	1050	4.7	1306	7830	-49	-1520	1 0 0 0 0 0 0 0 0 0 1	
1320	8.1	1040	4.7	1329	8280	-29	-1040	1 1 0 0 1 0 0 0 0 0 1	
1340	8.2	1050	4.6	1349	8390	-6	-900	1 0 1 0 0 0 0 0 0 0 1	
SEQ # 2									
NOT	SEEN								
1010	5.9	0820	4.9	1030	6050	-28	-4050	1 0 0 1	RANGE ERROR 3593m
1060	6.2	0850	4.9	1070	6340	+19	-3650	1 1 0 0 1 1	
1010	5.9	0860	4.8	1040	6130	-18	-4000	1 1 0 0 1 1	AZIMUTH ERROR 17.2m
NOT	SEEN								
1030	5.8	0840	4.9	1054	6010	-4	-4000	1 0 0 1	BLIP SCAN RATIO 66%
1380	7.7	0790	5.0	1417	8130	-38	-1300	1 0 0 1 1 1	
1010	5.8	0810	4.9	1039	5950	-1[illegible]	-4100	1 0 1 1	
1010	5.9	0820	5.0	1037	6060	-17	-4050	1 0 0 1	
1020	5.9	0810	5.0	1046	6060	-9	-4000	1 0 0 1	
NOT	SEEN								
"	"								
"	"								
"	"								
"	"								

Test # 12 Firing Data

ALL ROUNDS TO TGT 167 7 MAR 73 105mm

SEQ #	EP M7	CH.	DFE	RANGE	MO	MV	QE	TOF
1	10° 263	4	6057	6210			549	23
2	05° 90	4	4655	5100			434	22
3	0° 106	5	4404	5910			437	24

RADAR AN/TPQ-31 LOCATION ~~3313/4244~~ 4216/3343 DATE 7 MAR 73 CHARGE 4 / 4 Q.E. 549 / 434 PROJECTILE 105mm

TEST #12 SEQ # 1 + #2 (LOCATE)

BLIP SCAN FP-263 A-0994 mils R-10,560m FP-90 A-1093 R-9500

FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIG AZ	PREDICTED ORIG RG	PREDICTED IMPACT AZ	PREDICTED IMPACT RG	BLIP SCAN	
0930	8.0	0800	4.9	0936	8230	-56	-2400	1 1 1 1 1 1 0 1	
0950	8.9	0810	5.1	0955	9130	-59	-1400	1 1 0 1 1 1 0 0 1 1	RANGE ERROR -1647 meters
0920	8.0	0780	5.2	0925	8150	-69	-2450	1 1 0 1 1 1 0 0 1	
0940	8.9	0780	5.0	0945	9150	-49	-1450	1 1 1 0 1 1 1 0 1	AZIMUTH ERROR -44.4 mils
1000	9.7	0900	6.7	1004	9360	+10	-700	1 1 1 0 1 1 1 0 1	
0980	9.2	0800	5.0	0987	9460	-7	-1050	1 1 1 0 1 1 1 0 1	BLIP SCAN RATIO 79%
0950	8.9	0820	5.0	0954	9150	-40	-1400	1 1 1 1 1 1 1 1 1	
0910	8.0	0790	5.1	0916	8230	-78	-2400	1 1 0 1 1 1 0 1 1	
0930	8.1	0820	5.2	0936	8330	-58	-2250	1 1 1 1 1 1 0 0 1	
0950	8.9	0740	5.1	0957	9140	-37	-1400	1 1 1 1 1 1 0 0 1	
0930	8.9	0750	5.0	0936	9130	-58	-1500	1 1 1 1 1 1 1 0 1	
[illegible]	8.9	0750	5.2	0946	9130	-48	-1500	1 1 0 1 1 1 0 1 1	
0950	8.9	0750	5.2	0956	9120	-38	-1450	1 0 0 1 1 1 1 0 1	
0990	9.8	0750	5.2	0998	10090	+4	-450	1 0 1 1 1 0 1 1 1	
0920	7.5	0730	5.2	0930	7690	-64	-2900	1 1 1 0 1 1 1 1 1	
		SEQ # 2							
1030	9.2	0720	5.3	1041	9460	+47	-450	1 1 1 0 0 0 0 0 1	RANGE ERROR +843 meters
1040	9.1	0180	5.6	1049	9340	+49	-390	1 1 1 0 0 0 0 0 1	
1098	8.2	0760	5.1	0977	8400	-14	-1400	1 1 1 1 0 0 0 0 1	AZIMUTH ERROR +45 mils
1020	8.2	0770	5.1	1030	8390	+36	-1150	1 1 1 0 0 0 0 1 1	
1050	9.1	0800	5.4	1058	9350	+62	-300	1 1 1 0 0 0 0 0 1	BLIP SCAN RATIO 44%
1000	8.3	0810	5.3	1008	8510	+14	-1200	1 0 0 0 0 0 0 1 1	
1020	8.4	0750	5.7	1031	8600	+35	-1000	1 1 0 0 0 0 0 0 1	
1050	9.0	0790	5.4	1061	9250	+65	-340	1 1 0 0 0 0 0 0 1	
1050	9.0	0770	5.5	1061	9250	+65	-340	1 1 0 0 0 0 0 0 1	
1060	9.1	0770	5.5	1052	8400	+58	-1120	1 0 0 0 0 0 0 1 1	
1040	8.2	0770	5.3	1051	8400	+57	-1120	1 0 0 0 0 0 1 1 1	
1020	8.3	0750	5.3	1030	8700	+36	-920	1 1 1 1 0 0 0 0 1	
1020	8.5	0760	5.2	1030	8720	+36	-900	1 1 0 0 0 0 0 1 1	
[illegible]	9.1	0750	5.2	1070	9370	+76	-190	1 1 1 0 0 0 0 1 1	
1010	7.5	0740	5.2	1015	7710	+21	-1800	1 0 0 0 0 1 1	

CPR AN/TPQ-31 LOCATION 3313/4264 DATE 7MAR73 CHARGE 5 QE 437 PROJECTILE 105mm

TIME	FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIG AZ	PREDICTED ORIG RG	PREDICTED IMPACT AZ	PREDICTED IMPACT RG	TEST #12 SEQ #3 (LOCATE) BLIP SCAN FP #106 AZ=1301 mils R=8750m
									TRACKED WRONG ROUND
	1040	6.5	0730	5.2	1080	6760	-221	-2500	1 0 1 1
	1050	6.4	0750	5.1	1074	6570	-227	-2700	1 1 1 1 0 1
	1020	8.2	0770	5.1	1032	8360	-269	-2250	1 1 1 1 1 1 1
	0950	6.0	0760	4.9	0968	6110	-333	-3500	TRACKED WRONG ROUND
									1 1 0 1 1 1
	1030	8.2	0730	5.1	1048	8540	-253	-2100	1 1 1 0 0 0 1
	1050	6.5	0750	4.9	1056	6650	-245	-2650	1 1 1 0 0 !
	1050	6.4	0770	5.0	1077	6610	-224	-2700	1 1 0 0 1
	1130	6.8	0760	5.1	1148	6940	-153	-2100	1 1 1 1 1 0 1 1 1
	1190	7.3	0780	5.1	1225	7640	-76	-1250	1 0 0 1 1
	1100	6.7	0750	5.1	1123	6860	-118	-2300	1 1 1 0 0 1 1
	1130	6.9	0800	5.2	1151	7090	-150	-2000	1 1 1 0 0 1 1 1
	1150	7.0	0740	5.1	1178	7250	-123	-1750	1 1 1 0 1 1
	1130	6.8	0740	5.0	1163	7090	-138	-1950	1 1 0 1 1
	AVERAGE		RANGE		ERROR		-2289 meters		
	AVERAGE		AZIMUTH		ERROR		-19.9 mils		
	BLIP		SCAN		RATIO		76%		

Test # 13 Firing Data

FP-710 27 FEB 73 155 mm

SEQ#	TGT	CH	DEF	RANGE	MIO	MV	QE	TOF
1	2713/3556 42°	6	4714	9220	1599	463	416	29.9
2	2655/3612 28°	6	4803	9760	1514	463	458	32
3	2700/3546 [illegible]	6	4730	9370	1659	463	428	31

MASK ⊅ 0.5°

RADAR AN/TPQ-31 LOCATION ~~2399/3184~~ 2484/3290 DATE 27 FEB 73 CHARGE #1- 6 #2- 6 #3- 6 QE #1-X.L #2-458 #3-428 PROJECTILE 155

TEST # 13
SEQ #1, #2, #3 (CONFIRM)

BLIP SCAN FP-710 A-1327 R-10.520

ROUND	TIME	FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG	PREDICTED ORIG AZ	PREDICTED ORIG RG	PREDICTED IMPACT AZ	PREDICTED IMPACT RG	BLIP SCAN
1		1350	10.5	0840	3.7	1360	10950	SEQ #1		0 0 1 1 1 0 0 0 1 1
2										
3		1330	10.7	0690	4.1	1344	11150	SEQ #2		0 0 1 1 0 0 0 0 0 1
4										
5		1350	10.8	0910	3.7	1358	11210	SEQ #3		0 0 0 1 0 0 0 0 1 1
6										
7		ONLY FIRST ROUNDS OF EACH SEQ								0 0 0 1 1 0 0 0 1
8		WAS RECORDED.								
9										
10		AZIMUTH ERROR WHICH HAS								
11		OCCURED AMOUNTS TO APPROX.								
12		50 MILS. THE CAUSE OF								
13		ERROR IS NOT KNOWN AT THIS								
14		TIME.								
15										
16		BLIP		SCAN		RATIO		55%		
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										

Test # 13A Firing Data

FP-705 25 FEB 73 155mm

SEQ #	TGT	CH	DEF	RANGE	MO	MV	QE	TOF
1	2712/3556	6	4950	7650	1107 up	463	305	24
2	2758/3612	6	5040	8380	1259 up	463	349	27
3	[illegible]	6	4880	8130	1209	463	331	28

RADAR AN/TPQ-31 LOCATION ~~2399/3184~~ 2484/3299 DATE 23 FEB 73 CHARGE #1 6 #2 6 #3 6 QE #1 305 #2 349 #3 331 PROJECTILE 155

TEST #13A SEQ #1, #2, #3 (LOCATE) BLIP SCAN FP-705 A- 1495 mils R- 10150 METERS

ROUND	TIME	FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIG AZ	PREDICTED ORIG RG	~~PREDICTED IMPACT~~ AZ / RG	BLIP SCAN
1		1485	9.8	0940	4.6	1496	10125	SEQ #1	SEQ #1
2		1475	9.6	0940	4.6	1489	9680	"	RANGE ERROR 148m
3		1480	9.6	0940	4.6	1493	9900	"	AZIMUTH ERROR +35 m/
4		1500	9.8	0940	4.7	1514	10130	"	BLIP SCAN RATIO 9[illegible]
5		1490	9.7	0940	4.6	1504	10010	"	
6		1490	9.8	0940	4.6	1503	10125	"	
7		1486	10.0	0830	4.5	1507	10520	SEQ #2	SEQ #2
8		1487	9.7	0850	4.5	1506	10140	"	RANGE ERROR 170m
9		1483	10.0	0835	4.6	1504	10450	"	AZIMUTH ERROR +10 m/
10		1480	9.7	0840	4.6	1508	10310	"	BLIP SCAN RATIO 100%
11		1483	9.7	0840	4.5	1500	10090	"	
12		1485	9.6	0840	4.5	1505	10040	"	
13		1476	9.5	0960	4.4	1504	10210	SEQ #3	SEQ #3
14		1480	9.6	0960	4.5	1508	10310	"	RANGE ERROR 122m
15		1470	9.5	0940	4.5	1496	10150	"	AZIMUTH ERROR +65 m/
16		1475	9.5	0950	4.5	1504	10190	"	BLIP SCAN RATIO 100%
17		1473	9.6	0950	4.4	1500	10320	"	
18		1470	9.6	0950	4.4	1497	10310	"	
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									
33									

F-5-48

Test #15A Firing Data

FP-24 21 FEB 73. 8" HOW.

SEQ#	TGT.	CH	DEF	RANGE	MO	MV	QE	TOF	
1	745	7	4900	15,000	2890	590	546	47	10°
2	727	6	4900	13,1000	2600	500	618	46	11.5°

RADAR AN/TPQ-31 LOCATION 3270/2495 DATE 21 FEB 73 CHARGE 7 QE 546 PROJECTILE 8" HOW

POA 2484/3230

EP=224 TGT-745 BLIP SCAN TEST #15A SEQ #1

ROUND	TIME	FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIG AZ MILS	PREDICTED ORIG RG KM	PREDICTED IMPACT AZ MILS	PREDICTED IMPACT RG KM	BLIP SCAN 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
1		NOT SEE!								ANTENNA TILT +3°
2		"								"
3		"								"
4		"								ANTENNA TILT +3°
5		"								"
6		"								"
7		"								"
8		"								"
9		"								"
10		"								"
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
[illegible]										
[illegible]										
[illegible]										

RADAR AN/TPQ-31 LOCATION 3270/2495 DATE 21 FEB 73 CHARGE 6 QE 618 PROJECTILE 8" How

FP-24 TGT-727 BLIP SCAN TEST # 100 SEQ # 2

ROUND	TIME	FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIG AZ	PREDICTED ORIG RG	PREDICTED IMPACT AZ	PREDICTED IMPACT RG	BLIP SCAN		
1		1550	14.8	0960	4.5	1590	15420			0 0 1 1 1 1 0 0 0 0 0 1	18	RPM
2		1530	13.8	0950	4.6	1540	14360			0 0 1 1 1 1 0 0 0 0 0 1		
3		1560	15.6	0960	4.75	1570	16320			0 0 1 1 1 1 0 1 0 0 1 1		
4		1530	15.1	0950	4.55	1535	15500			0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 1	25	RPM
5		1520	15.2	0950	4.5	1528	15820			0 0 1 1 1 1 0 0 1 0 0 1	18	RPM
6		1530	15.2	0960	4.5	1536	15790			0 0 1 1 0 1 0 0 0 0 0 1		
7		1520	14.4	0900	4.65	1535	15340			0 0 1 1 0 0 0 0 0 0 1 1		
8		1510	14.1	0920	4.5	1520	14670			0 0 1 1 1 0 0 0 0 0 0 1		
9		1550	15.65	0930	4.7	1560	16310			0 1 1 1 0 0 0 0 0 0 0 1		
10		1460	13.5	0850	4.6	1470	14050			0 0 1 1 0 0 0 0 0 0 1 1		
11		1450	14.8	0830	4.5	1458	15400			0 0 1 1 0 0 0 0 0 0 0 1		
12		1460	13.4	0830	4.5	1468	14900			0 0 1 1 0 0 0 0 0 0 1 1		
13		1460	15.2	0830	4.5	1470	15790			0 0 1 1 1 0 0 0 0 0 0 1		
14		1460	14.8	0810	4.5	1470	15440			0 0 1 1 0 0 0 0 0 0 0 1		
15		1460	15.2	0830	4.65	1469	15820			0 0 1 1 0 0 0 0 0 0 0 1		
16												
17												
18		AVERAGE RANGE ERROR - 902.6 meters										
19		" AZIMUTH " -23.5 mils										
20		BLIP SCAN RATIO - 41%										
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
32												
33												
34												
35												
36												

Test # 16 Firing Data

ALL ROUNDS TO TGT 745 22 FEB 73 8" HOW

SEQ#	FP	CH	DEF	RANGE	MO	MV	QE	TOF	
1	25	7	4890	16,200	3198		671	55	9.5°
2	23	7	4900	14,500	2573		518	44	11°

RADAR AN/TPQ-31 LOCATION 2484/3290 DATE 22FEB73 CHARGE 7 QE ~~[illegible]~~ 671 PROJECTILE 8" HOW

TEST # 16
SeQ # 1

BLIP SCAN

ROUND	TIME	FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIG AZ	PREDICTED ORIG RG	PREDICTED IMPACT AZ	PREDICTED IMPACT RG	BLIP SCAN
1										
2		NO		VALID		DATA		ATTAINED		
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
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23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										
36										

RADAR AN/TPQ-31 LOCATION ____ DATE 22 FEB 73 CHARGE 7 QE 518 PROJECTILE 8" HOW.

TEST #16
SEQ #2

BLIP SCAN

FP 23 ... TGT 745
A-1510
R-15400

ROUND	TIME	FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIG AZ MILS	PREDICTED ORIG RG KM	~~PREDICTED IMPACT~~ AZ	~~PREDICTED IMPACT~~ RG	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		NOT	SEEN	0550	3.6					I	M	P	A	C	T											
2		1475	13.3	0620	3.7	1510	15460	Ø	-460	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1
3		NOT	SEEN	0550	3.7					I	M	P	A	C	T										1	1
4		1485	14.6	0660	3.7	1490	14,960	-20	-520	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
5		1505	14.6	0530	3.7	1516	15,000	+6	-380	1	1	1	0	1	1	1	0	0	0	0	0	0	0	1	1	
6		1470	15.0	0505	3.7	1476	15,400	-34	-500	1	1	1	1	1	1	0	0	0	0	1	0	0	0	1	1	
7		1470	15.0	0600	3.8	1476	15,410	-34	-510	1	1	1	0	0	0	1	0	0	0	0	1	0	0	1	1	
8		1490	15.2	0565	3.8	1495	15,620	-15	+260	1	1	1	1	0	0	0	0	0	0	1	0	1	0	0	1	1
9		1490	15.0	0550	3.7	1496	15,420	-14	+140	1	1	0	0	0	1	1	0	0	0	0	1	0	0	0	1	1
10		1480	14.2	0560	3.8	1487	14,560	-23	-960	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
11																										
12		AVERAGE		RANGE		ERROR		301 meters																		
13		"		AZIMUTH		ERROR		-16.7 mils																		
14		BLIP		SCAN		RATIO		40%																		

F-5-54

Test #17. Firing Data

Two sequences were scheduled. Only the first sequence was ~~fired~~ fired. This was due to problems which occured with the gun.

FP-30 . SEQ# 1 6 MAR 73 175mm

TGT.	CH	DEF	RANGE	MO	MV	QE	TOF
51/35	2	4885	20,500	6799	704.1	680	67

0° MASK ANGLE

TGT - 4910 31.2 Km.

RADAR AN/TPQ-31 LOCATION ~~5276/3296~~ 5278 3280 DATE 6 Mar 73 CHARGE ______ QE ______ PROJECTILE 175mm

TEST #17
SEQ #1
(CONFIRM)

BLIP SCAN

FP-30
A-4937m
R-5625 meters

TIME	FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIG AZ	PREDICTED ORIG RG	PREDICTED IMPACT AZ	PREDICTED IMPACT RG	BLIP SCAN (CONFIRM)
	NOT	SEEN							
	"	"							
	"	"							
	"	"							
	"	"							
	4920	6.6	4900	11.2	4923	6125	-14	+470	0 1 1 0 1 1
	NOT	SEEN	---	---	---				
	4920	6.5	4895	12.2	4913	5925	-24	+290	0 0 1 1 1 0
	4905	6.4	4900	13.8	4905	5650	-32	+150	1 1 0 0 1 0
	4920	6.5	4900	12.1	4923	5950	-14	+290	1 1 0 0 1 1
	4905	6.1	4900	13.9	4903	5825	-35	+310	0 1 1 0 1 1
	4920	6.0	4905	12.1	4925	5400	-12	-210	1 0 1 1 0 0
	4920	6.9	4910	13.3	4920	6250	-17	+590	1 0 1 1 1 1
	4920	6.5	4910	13.7	4923	5800	-14	+130	0 1 0 1 1 1
	4920	6.1	4910	13.8	4921	5325	-16	-270	0 1 0 1 1 1
	4915	6.4	4905	13.5	4918	5700	-19	+90	1 0 1 1 1 1

AVERAGE RANGE ERROR +223 meters
AVERAGE AZIMUTH ERROR -19.7 mils
BLIP SCAN RATIO 60%

Test #18 Firing Data

F.P.-90 6 MAR 73 4.2" + 81mm

SEQ#	TGT	CH	DEF	RANGE	MO	MV	QE	TOF
1	10m So. #36	19 4/8	4825	3350	1155	212.6	900	31
2	2010 So. #36	19 5/8	4693	3290	1130	210	900	31
3	18	7	4868	3580	1000	230	1004	29
4	11	7	4758	3560	1000	230	1020	29

5510
310 7.42

0° MASK ANGLE

RADAR AN/TPQ-31 LOCATION ~~5339/3339~~ DATE 6MAR73 CHARGE 19 4/8 QE 900 m PROJECTILE 4.2"

First Detection		Last Detection		Predicted Orig		~~Predicted~~		TEST # 18 SEQ # 1 (CONFIRM)									
AZ MILS	RG KM	AZ MILS	RG KM	AZ	RG	AZ	RG	BLIP SCAN FP-90 A-5985 mils R-5400 METERS									
5960	5.5	5700	6.9	5978	5440	-7	-20	1	1	1	1	1	1	1	1	0	0
5930	5.6	5670	7.1	5950	5540	-35	-200	1	1	1	1	1	1	1	1	1	0
5920	5.5	5650	7.1	5945	5420	-40	-180	1	1	1	1	1	1	0	1	0	0
5950	5.6	5690	6.8	5968	5550	-17	-130	1	1	1	1	1	1	1	1	0	0
5930	5.6	5620	7.6	5956	5530	-29	-160	0	1	1	1	1	1	1	1	1	0
5950	5.6	5630	7.3	5976	5525	-9	-90	1	1	1	1	1	1	1	1	1	0
5960	5.6	5650	7.3	5983	5520	-2	-80	1	1	1	1	1	1	1	1	1	1
5930	5.6	5650	7.3	5950	5530	-35	-262	1	1	1	1	1	1	1	1	1	1
5920	5.6	5660	7.2	5938	5525	-50	-240	1	1	1	1	1	1	1	1	1	1
5950	5.5	5670	7.1	5970	5440	-15	-40	1	1	1	1	1	1	1	1	1	1

AVERAGE RANGE ERROR -136 METERS

AVERAGE AZIMUTH ERROR -23.9 mils

BLIP SCAN RATIO 89%

ANTENNA SPEED 24 RPM

SYS AN/TPQ-31 LOCATION 5276/3296 DATE 6 Mar 73 CHARGE 19 4/8 QE 900 m PROJECTILE 4.2"

TEST # 18
SEQ # 2
(CONFIRM)

BLIP SCAN

FP-90
A-5985 m
R-5400 METERS

FIRST DETECTION		LAST DETECTION		PREDICTED ORIG		~~PREDICTED IMPACT~~											
AZ MILS	RG KM	AZ MILS	RG KM	AZ MILS	RG M	AZ	RG										
5960	5.6	5650	6.9	5982	5540	-3	-100	1	1	1	1	1	1	1	1	1	1
5950	5.6	5600	7.1	5974	5550	-11	-110	0	1	1	1	1	1	1	0	0	1
5970	5.6	5630	7.0	5997	5560	+72	-140	1	1	0	0	1	1	1	1	0	1
5965	5.7	5630	7.1	5987	5640	+2	-200	1	1	1	0	1	1	1	1	0	0
5960	5.7	5630	7.1	5980	5650	-5	-200	1	1	1	0	1	1	1	1	0	0
5975	5.6	5620	7.2	6000	5550	+15	+120	1	1	1	0	0	1	1	1	1	0
5950	5.6	5600	7.2	5978	5540	-7	-100	1	1	1	0	1	1	1	1	1	0
5945	5.6	5600	7.1	5968	5540	-17	-120	1	1	1	0	1	1	1	1	1	0
5960	5.6	5600	7.1	5987	5550	+2	-110	1	1	1	0	1	1	1	1	0	0
5965	5.6	5610	7.2	5990	5530	+5	-100	1	1	1	1	1	1	1	1	0	0

AVERAGE	RANGE	ERROR	166 meters
AVERAGE	AZIMUTH	ERROR	8.9 mils
BLIP	SCAN	RATIO	86%
ANTENNA	RATED	24 RPM	

AN/TPQ-31 LOCATION 5276/3296 DATE 6MAR73 CHARGE [redacted] 7 QE 1004 PROJECTILE 81mm

TEST # 1B SEQ # 3 (CONFIRM) BLIP SCAN FP-90 A-5985 R-5400 METERS

FIRST DETECTION AZ MILS	FIRST DETECTION RG KM	LAST DETECTION AZ MILS	LAST DETECTION RG KM	PREDICTED ORIG AZ	PREDICTED ORIG RG	PREDICTED IMPACT AZ	PREDICTED IMPACT RG										
5930	5.6	5720	6.9	5946	5540	-39	-210	1	1	1	0	1	1	1	1	1	1
5930	5.7	5720	7.1	5945	5625	-40	-260	1	1	1	0	0	1	1	1	1	1
5950	5.6	5730	1.0	5968	5525	-17	-120	1	1	1	0	0	0	1	1	0	1
5940	5.6	5700	7.1	5958	5510	-27	-140	0	1	1	0	0	0	1	1	0	1
5930	5.6	5710	7.0	5950	5540	-35	-200	0	1	1	1	1	0	0	1	1	1
5950	5.6	5700	7.1	5970	5520	-15	-100	1	1	1	0	0	0	1	1	1	1
5950	5.6	5700	7.0	5970	5520	-15	-120	1	1	1	1	0	0	0	1	1	1
5950	5.6	5710	6.9	5968	5530	-17	-120	1	1	1	0	0	0	1	1	1	1
5960	5.6	5760	6.9	5978	5530	-7	-100	1	1	1	0	0	0	1	1	1	1
5960	5.6	5700	6.9	5980	5540	-5	-100	1	1	1	0	0	0	1	1	1	1

AVERAGE RANGE ERROR -145 METERS
AVERAGE AZIMUTH ERROR -21.7 mils
BLIP SCAN RATIO 70%